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ALTITUDE DEVELOPMENTAL TESTING OF THE J-2S ROCKET ENGINE IN ROCKET DEVELOPMENT TEST CELL (J-4) (TESTS J4-1902-08, -11, AND -12)

D. E. Franklin and C. R. Tinsley

ARO, Inc.

April 1970

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ROCKET TEST FACILITY
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NOTICES

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FOREWORD

The work reported herein was sponsored by the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center (MSFC) (PM-EP-J), under System 921E, Project 9194.

The results of the tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract F40600-69-C-0001. Program direction was provided by NASA/MSFC, technical and engineering liaison was provided by North American Rockwell Corporation, Rocketdyne Division, manufacturer of the J-2S rocket engine, and McDonnell Douglas Astronautics Company, manufacturer of the S-IVB stage. The testing reported herein was conducted on April 2, May 6, and May 9, 1969, in Rocket Development Test Cell (J-4) of the Rocket Test Facility (RTF) under ARO Project No. KA1902. The manuscript was submitted for publication on January 9, 1970.

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This technical report has been reviewed and is approved.

Walter C. Knapp
Lt Colonel, USAF
AF Representative, RTF
Directorate of Test

Roy R. Croy, Jr.
Colonel, USAF
Director of Test

ABSTRACT

Six firings of the Rocketdyne J-2S rocket engine were conducted in Test Cell J-4 of the Rocket Test Facility on April 2, May 6, and May 9, 1969 These firings were accomplished during test periods J4-1902-08, -11, and -12 at pressure altitudes at engine start ranging from 80,500 to 101,500 ft. Objectives were to develop high-thrust idle-mode operation capability and to develop transition capability from high-thrust idle mode to main stage without utilization of the solid-propellant turbine starter. The first attempt at high-thrust idle-mode operation (firing 08A) was not successful; however, during test periods 11 and 12 transition was accomplished from low- to high-thrust (approximately 4000- to 50,000-lbf thrust) idle mode and from high-thrust idle mode to main stage during firing 12C.

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NOMENCLATURE

A	Area, in.^{2}
ASI	Augmented spark igniter
CCP	Customer connect panel
EBW	Exploding bridgewire
FM	Frequency modulation
MFV	Main fuel valve
MOV	Main oxidizer value
O/F	Propellant mixture ratio, oxidizer to fuel, by weight
SPTS	Solid-propellant turbine starter
T/C	Thrust chamber

t_0 Time at which helium control and idle-mode solenoids are energized, engine start

VSC Vibration safety counts, defined as engine vibration in excess of 150 g rms in a 960- to 6000-Hz frequency range

SUBSCRIPTS

f Force

m Mass

t Throat

SECTION I
INTRODUCTION

Testing of the Rocketdyne J-2S rocket engine using an S-IVB battleship stage has been in progress at AEDC since December 1968 Reported herein are the results of six firings conducted during test periods J4-1902-08, -11, and -12, on April 2, May 6, and May 9, 1969, respectively. The engine serial number for test period 08 was J-112-1, for test period 11 was J-112-1B, and for test period 12 was J-112-1C. The major objectives for these test periods were (1) to develop high-thrust (50,000-lbf) idle-mode capability and (2) to develop transition capability from high-thrust idle mode to main-stage operation without utilization of a solid-propellant turbine starter.

The firings reported herein were accomplished in Propulsion Engine Test Cell (J-4) (Figs. 1 and 2, Appendix I) of the Large Rocket Facility (LRF). The firings were accomplished at pressure altitudes ranging from approximately 80,500 to 101,500 ft (geometric pressure altitude, z, Ref. 1) at engine start. Data collected to accomplish the test objectives are presented herein. The results of the previous test periods are presented in Refs. 2 and 3.

SECTION II
APPARATUS

2.1 TEST ARTICLE

The test article was a J-2S rocket engine (Fig. 3) designed and developed by Rocketdyne Division of North American Rockwell Corporation. The engine uses liquid oxygen and liquid hydrogen as propellants and is designed to operate either in idle mode at a nominal thrust of 5000 lbf and mixture ratio of 2.5 or at main stage at any precalibrated thrust level between 230,000 and 265,000 lbf at a mixture ratio of 5.5. The engine design is capable of transition from idle-mode to main-stage operation after a minimum of 1-sec idle mode; from main stage the engine can either be shut down or make a transition back to idle-mode operation before shutdown. An S-IVB battleship stage was used to supply propellants to the engine. A schematic of the battleship stage is presented in Fig. 4.

Listings of major engine components and engine orifices for this test period are presented in Tables I and II, respectively (Appendix II). All engine modifications and component replacements performed during this report period are presented in Tables III and IV, respectively.

2.1.1 J-2S Rocket Engine

The J-2S rocket engine (Figs. 3 and 5, Ref. 4) features the following major components:

1. Thrust Chamber—The tubular-walled, bell-shaped thrust chamber consists of an 18.6-in.-diam combustion chamber with a throat diameter of 12.192 in., a characteristic length (L*) of 35.4, and a

divergent nozzle with an expansion ratio of 39.62. Thrust chamber length (from the injector flange to the nozzle exit) is 108.6 in. Cooling is accomplished by the circulation of engine fuel flow downward from the fuel manifold through 180 tubes and then upward through 360 tubes to the injector and by film cooling inside the combustion chamber.

2. Thrust Chamber Injector The injector is a concentric-orificed (concentric fuel orifices around the oxidizer post orifices), porous-faced injector. Fuel and oxidizer injector orifice areas are 19.2 and 5.9 in.^{2}, respectively. The oxidizer portion is compartmentalized, the outer compartment supplying oxidizer during main-stage operation only. The porous material, forming the injector face, allows approximately 3.5 percent of main-stage fuel flow to transpiration cool the face of the injector.

3. Augmented Spark Igniter–The augmented spark igniter unit is mounted on the thrust chamber injector and supplies the initial energy source to ignite propellants in the main combustion chamber. The augmented spark igniter chamber is an integral part of the thrust chamber injector. Fuel and oxidizer are ignited in the combustion area by two spark plugs.

4. Fuel Turbopump–The fuel turbopump is a one and one-half stage, centrifugal-flow unit, powered by a direct-drive, two-stage turbine. The pump is self lubricated and nominally produces, at the 265,000-lbf-thrust rated condition, a head rise of 60,300 ft of liquid hydrogen at a flow rate of 9750 gpm for a rotor speed of 29,800 rpm.

5. Oxidizer Turbopump–The oxidizer turbopump is a single-stage, centrifugal-flow unit, powered by a direct-drive, two-stage turbine. The pump is self lubricated and nominally produces, at the 265,000-lbf-thrust rated condition, a head rise of 3250 ft of liquid oxygen at a flow rate of 3310 gpm for a rotor speed of 10,500 rpm.

6. Propellant Utilization Valve–The motor-driven propellant utilization valve is a sleeve-type valve mounted on the oxidizer turbopump and bypasses liquid oxygen from the discharge to the inlet side of the pump to vary engine mixture ratio.

7. Main Oxidizer Valve–The main oxidizer valve is a pneumatically actuated, two-stage, butterfly-type valve located in the oxidizer high pressure duct between the turbopump and the injector. The first-stage actuator positions the main oxidizer valve at the 12-deg position to obtain initial main-stage-phase operation; the second-stage actuator ramps the main oxidizer valve full open to accelerate the engine to the main-stage operating level.

8. Main Fuel Valve The main fuel valve is a pneumatically actuated butterfly-type valve located in the fuel high pressure duct between the turbopump and the fuel manifold

9. Pneumatic Control Package The pneumatic control package controls all pneumatically operated engine valves and purges

10. Electrical Control Assembly The electrical control assembly provides the electrical logic required for proper sequencing of engine components during operation. The logic requires a minimum of 1-sec idle-mode operation before transition to main stage

11. Flight Instrumentation Package The instrumentation package contains sensors required to monitor critical engine parameters. The package provides environmental control for the sensors

12. Helium Tank–The helium tank has a volume of 4000 in^3 and provides a helium pressure supply to the engine pneumatic control system for three complete engine operational cycles.

13. Thrust Chamber Bypass Valve–The thrust chamber bypass valve is a pneumatically operated, normally open, butterfly-type valve which allows fuel to bypass the thrust chamber body during idle-mode operation.

14. Idle-Mode Valve–The idle-mode valve is a pneumatically operated ball-type valve which supplies liquid oxygen to the idle-mode compartment of the thrust chamber injector during both idle-mode and main-stage operation.

15. Hot Gas Tapoff Valve–The hot gas tapoff valve is a pneumatically operated butterfly-type valve which provides on-off control of combustion chamber gases to drive the propellant turbopumps.

16. Solid-Propellant Turbine Starter–The solid-propellant turbine starter provides the initial driving energy (transition to main stage) for the propellant turbopumps to prime the propellant feed systems and accelerate the turbopumps to 75 percent of their main-stage operating level. A three-start capability is provided.

2.1.2 S-IVB Battleship Stage

The S-IVB battleship stage, which is mechanically configured to simulate the S-IVB flightweight vehicle, is approximately 22 ft in diameter and 49 ft long and has a maximum propellant capacity of 43.000 lb of liquid hydrogen and 194,000 lb of liquid oxygen. The propellant tanks, fuel above oxidizer, are separated by a common bulkhead. Propellant prevalves, in the low pressure ducts (external to the tanks) interfacing the

stage and engine, retain propellants in the stage until being admitted into the engine to the main propellant valves and serve as emergency engine shutoff valves Vent and relief valve systems are provided for both propellant tanks

Pressurization of the fuel and oxidizer tanks was accomplished by facility systems using hydrogen and helium, respectively, as the pressurizing gases The engine-supplied gaseous hydrogen and gaseous oxygen for fuel and oxidizer tank pressurization during flight were routed to the respective facility venting systems

2.2 TEST CELL

Propulsion Engine Test Cell J-4, Fig 2, is a vertically oriented test unit designed for static testing of liquid-propellant rocket engines and propulsion systems at pressure altitudes of 100,000 ft. The basic cell construction provides a 1 5-million-lbf-thrust capacity The cell consists of four major components (1) test capsule, 48 ft in diameter and 82 ft in height, situated at grade level and containing the test article, (2) spray chamber, 100 ft in diameter and 250 ft in depth, located directly beneath the test capsule to provide exhaust gas cooling and dehumidification, (3) coolant water, steam, nitrogen (gaseous and liquid), hydrogen (gaseous and liquid), liquid oxygen, and gaseous-helium storage and delivery systems for operation of the cell and test article, and (4) control building, containing test article controls, test cell controls, and data acquisition equipment. Exhaust machinery is connected with the spray chamber and maintains a minimum test cell pressure before and after the engine firing and exhausts the products of combustion from the engine firing. Before a firing, the facility steam ejector, in series with the exhaust machinery, provides a pressure altitude of 100,000 ft in the test capsule. A detailed description of the test cell is presented in Ref. 5.

The battleship stage and the J-2S engine were oriented vertically downward on the centerline of the diffuser/steam ejector assembly. This assembly consisted of a diffuser duct (20 ft in diameter by 150 ft in length), a centerbody steam ejector within the diffuser duct, a diffuser insert (13.5 ft in diameter by 30 ft in length) at the inlet to the diffuser duct, and a gaseous-nitrogen annular ejector above the diffuser insert. The diffuser insert was provided for dynamic pressure recovery of the engine exhaust gases and to maintain engine ambient pressure altitude (attained by the steam ejector) during the engine firing. The annular ejector was provided to suppress steam recirculation into the test capsule during steam ejector shutdown. The test cell was also equipped with (1) a gaseous-nitrogen purge system for continuously inerting the normal air in-leakage of the cell, (2) a gaseous-nitrogen repressurization system for raising test cell pressure, after engine cutoff, to a level equal to spray chamber pressure and for rapid emergency inerting of the capsule, and (3) a spray chamber liquid-nitrogen supply and distribution manifold for initially inerting the spray chamber and exhaust ducting and for increasing the molecular weight of the hydrogen-rich exhaust products.

2.3 INSTRUMENTATION

Instrumentation systems were provided to measure engine, stage, and facility parameters. The engine instrumentation was comprised of (1) flight instrumentation for the measurement of critical engine parameters and (2) facility instrumentation which was

provided to verify the flight instrumentation and to measure additional engine parameters. The flight instrumentation was provided and calibrated by the engine manufacturer, facility instrumentation was initially calibrated and is periodically recalibrated at AEDC Appendix III contains a list of all measured engine test parameters and the locations of selected sensing points

Pressure measurements were made using strain-gage and capacitance-type pressure transducers. Temperature measurements were made using resistance temperature transducers and thermocouples. Oxidizer and fuel turbopump shaft speeds were sensed by magnetic pickup. Fuel and oxidizer flow rates to the engine were measured by turbine-type flowmeters which are an integral part of the engine. Engine vibrations were measured by piezoelectric accelerometers. Primary engine and stage valves were instrumented with linear potentiometers and limit switches.

The data acquisition systems were calibrated by (1) precision electrical shunt resistance substitution for the pressure transducers and resistance temperature transducer units, (2) voltage substitution for the thermocouples, (3) frequency substitution for shaft speeds and flowmeters, and (4) frequency-voltage substitution for accelerometers and capacitance-type pressure transducer.

The types of data acquisition and recording systems used during this test period were (1) a multiple-input digital data acquisition system scanning each parameter at 50 samples per second and recording on magnetic tape, (2) single input, continuous-recording FM systems recording on magnetic tape, (3) photographically recording galvanometer oscillographs, (4) direct-inking, null-balance, potentiometer-type X-Y plotters and strip charts, and (5) optical data recorders. Applicable systems were calibrated before each test (atmospheric and altitude calibrations). Television cameras, in conjunction with video tape recorders, were used to provide visual coverage during an engine firing, as well as for replay capability for immediate examination of unexpected events.

2.4 CONTROLS

Control of the J-2S engine, battleship stage, and test cell systems during the terminal countdown was provided from the test cell control room. A facility control logic network was provided to interconnect the engine control system, major stage systems, the engine safety cutoff system, the observer cutoff circuits, and the countdown sequencer. A schematic of the engine start control logic is presented in Fig. 6. The sequence of engine events for start and shutdown is presented in Figs. 7a and b. The engine was modified for this series of tests to transition to high-thrust idle mode and from high thrust to main stage.

SECTION III
PROCEDURE

Preoperational procedures were begun several hours before the test period. All consumable storage systems were replenished, and engine inspections, leak checks, and drying procedures were conducted. Propellant tank pressurants and engine pneumatic and purge gas samples were taken to ensure that specification requirements were met.

Chemical analysis of propellants was provided by the propellant suppliers Facility sequence, engine sequence, and engine abort checks were conducted within a 24-hr time period before an engine firing to verify the proper sequence of events Facility and engine sequence checks consisted of verifying the timing of valves and events to be within specified limits, the abort checks consisted of electrically simulating engine malfunctions to verify the occurrence of an automatic engine cutoff signal. A final engine sequence check was conducted immediately preceding the test period.

Oxidizer dome and thrust chamber jacket purges were initiated before evacuating the test cell After completion of instrumentation calibrations at atmospheric conditions, the test cell was evacuated to approximately 0.5 psia with the exhaust machinery, and instrumentation calibrations at altitude conditions were conducted Immediately before loading propellants on board the vehicle, the cell and exhaust-ducting atmosphere was inerted. At this same time, the cell nitrogen purge was initiated for the duration of the test period. The vehicle propellant tanks were then loaded, and the remainder of the terminal countdown was conducted. Table V presents the engine purges during the terminal countdown and immediately following the engine firing.

SECTION IV
RESULTS AND DISCUSSION

4.1 TEST SUMMARY

Six firings of the Rocketdyne J-2S rocket engine were conducted during test periods J4-1902-08, -11, and -12 on April 2, May 6, and May 9, 1969, respectively. Pressure altitude at engine start ranged from 80,500 to 101,500 ft.

The two major objectives for these test periods were (1) to develop high-thrust idle-mode capability and (2) to develop transition capability from high-thrust idle mode to main stage without utilization of a solid-propellant turbine starter. A summary of significant test variables and results is presented below.

Firing J4-1902-	08A	11A	11B	12A	12B	12C
Fuel pump inlet pressure, psia	33.2	40.1	39.9	40.0	40.0	39.8
Oxidizer pump inlet pressure, psia	39.8	38.6	44.4	39.6	44.4	45.0
Main oxidizer valve first stage position, deg	12	10	10	11	11	11
Propellant utilization valve position at t_0	Null	Open	Null	Open	Null	Null

Firing J4-1902-	08A	11A	11B	12A	12B	12C
Hot gas tapoff valve open limit, deg	38	53	53	53	53	53
Fuel bypass line orifice diameter, in.	1.751	1.749	1.749	1.749	1.749	1.749
Idle-mode oxidizer line orifice diameter, in.	Open	0.900	0.900	0.900	0.900	0.900
Successful transition to high-thrust idle-mode operation	No	Yes	No	Yes	Yes	Yes
Successful transition to steady-state main-stage operation[1]	[2]	[2]	[2]	[2]	No	Yes

[1]Transition to main stage was accomplished without solid-propellant turbine starter burn.

[2]Transition to main stage was not an objective for this firing

Test requirements and specific test results are summarized in Table VI. Start and shutdown transient operating times for selected engine valves are presented in Table VII. Figure 8 shows engine start conditions for propellant pump inlets and helium tank. Total engine propellant flow rate, mixture ratio, propellant systems performance, and thrust chamber and fuel injection behaviors are presented in Figs. 9 through 32.

Data presented in subsequent sections are from the digital data acquisition system except where indicated otherwise. Propellant flow rates are based on pump discharge temperatures and pressures and on engine flowmeter calibration constants supplied by the engine manufacturer (5.50 and 2.00 cycles/gal for the oxidizer and fuel flowmeters, respectively).

4.2 TEST RESULTS

4.2.1 Firing J4-1902-08A

Firing 08A consisted of 20.9 sec of low-thrust idle-mode operation followed by 4.4 sec of high-thrust idle-mode operation. The objective of this firing was to determine J-2S engine operating characteristics and performance under high-thrust idle-mode operation. High-thrust idle mode was not successfully accomplished. The scheduled 20 sec of high-thrust idle mode was terminated prematurely after 4.4 sec when the tapoff manifold and fuel injection temperatures exceeded established redline limits. Thrust chamber damage was incurred on this firing, specifics of which are discussed in Section 4.6.1.

4.2.2 Firing J4-1902-11A

Firing 11A consisted of 10.2 sec of low-thrust idle-mode operation followed by 16.0 sec of high-thrust idle-mode operation The objective of this firing was to evaluate the effects of increasing open position of hot gas tapoff valve from 38 to 53 deg and reducing oxidizer flow on engine low-thrust and high-thrust idle-mode operation Transition from low-thrust to high-thrust idle mode was successfully accomplished, however, steady-state operation could not be maintained because of fuel turbine icing problems Details of this turbine icing are discussed in Section 4 3.

4.2.3 Firing J4-1902-11B

Firing 11B consisted of 20.0 sec of low-thrust idle-mode operation followed by 15.0 sec of scheduled high-thrust idle-mode operation. The objective of this firing was to evaluate the effects of oxidizer pump inlet pressure and delayed prevalve opening on results obtained during firing 11A with 10 sec of additional low-thrust idle-mode operation.

Although the scheduled high-thrust idle-mode duration was 15.0 sec, the firing was terminated a few milliseconds prematurely by an observer cutoff because thrust chamber skin and hot gas tapoff manifold temperatures exceeded established redline limits. Analysis of data revealed that the fuel turbine had not operated during the firing However, the main oxidizer valve did open to its first-stage position as scheduled for high-thrust idle-mode operation, thus resulting in an abnormally high oxidizer-to-fuel ratio and an observer cutoff. Posttest engine inspection revealed that ice had formed inside the turbine assembly.

4.2.4 Firing J4-1902-12A

Firing 12A consisted of 10.1 sec of low-thrust idle mode followed by 12.7 sec of high-thrust idle mode and 1.7 sec of transition into main-stage operation. The objective of this firing was to repeat firing 11A with the main oxidizer valve first-stage angular position increased from 10 to 11 deg. The transition to main stage was not planned for this firing but was inadvertently obtained when the 15-sec main-stage control timer expired prematurely after 12.7 sec (Section 4.6.2).

4.2.5 Firing J4-1902-12B

Firing 12B consisted of 20.5 sec of low-thrust idle-mode operation, 12.6 sec of high-thrust idle-mode operation, and 0.5 sec of main-stage operation. The objective of this firing was to evaluate the transition from high-thrust idle mode to main-stage operation without utilization of the solid-propellant turbine starter. The duration of high-thrust idle-mode operation for this firing was programmed for 15.0 sec, but the main-stage control timer again expired prematurely, as was encountered during firing 12A. Main-stage duration was programmed for 5 sec but was terminated prematurely after 0.5 sec by an observer cutoff when oxidizer pump inlet pressure exceeded established redline limits (Section 4.6.3).

4.2.6 Firing J4-1902-12C

Firing 12C consisted of 20.1 sec of low-thrust idle-mode operation, 12.6 sec of high-thrust idle-mode operation, and 8.2 sec of main-stage operation. The objective of this firing was to evaluate the transition from high-thrust idle mode to main-stage operation without utilization of the solid-propellant turbine starter. Start conditions were identical to those of firing 12B. The programmed durations of high-thrust idle-mode and main-stage operation were 15.0 and 5.0 sec, respectively. However, the main-stage control timer problem was encountered as during the two previous firings. Transition from low-thrust to high-thrust idle mode and transition from high-thrust to steady-state main stage without solid-propellant turbine starter burn were successfully accomplished during this firing.

4.3 DEVELOPMENT OF J-2S ENGINE TRANSITION CAPABILITY

The initial attempt to transition the J-2S engine from low-thrust to high-thrust idle mode was made during firing 08A. This firing was terminated prematurely 4.4 sec after initiation of high-thrust idle mode when the hot gas tapoff manifold temperature (Fig. 33) exceeded redline limits. The excessive temperature resulted from inadequate fuel flow to the combustion chamber when the fuel pump inducer cavitated. Cavitation was attributed to an excessive inducer back pressure at a time when the pump was not operating under normal design conditions. As a result, fuel recirculated through the pump causing loss of net positive suction head (Fig 34a) because of the rise in pump inlet temperature (Fig. 34b). The fuel pump head/flow ratio for the high-thrust idle-mode transient of firing 08A is compared with firing 11A and two previous main-stage transients in Fig. 34c. As can be observed, head/flow ratios were much higher than previously recorded. Pressure and temperature data recorded for the fuel pump are shown in Fig. 34b. The problems developing during this firing were eliminated for subsequent tests by increasing power to the turbines and reducing oxidizer flow. For test 11, the hot gas tapoff valve open position was changed from approximately 38 deg (used for test 08) to the original 53-deg position (Table I). Oxidizer flow was reduced by (1) installation of a 0.9-in.-diam orifice in the idle-mode oxidizer supply line (line diameter is 1.426 in.), (2) reduction of the main oxidizer valve first-stage open position from 12 to 10 deg, and (3) positioning the propellant utilization valve to open instead of null.

A successful transition from low-thrust to high-thrust idle mode was accomplished during firing 11A, but steady-state operation could not be maintained because of fuel turbine icing problems. At approximately t_0 + 15 sec, the fuel turbine inlet temperature decreased below 32°F (Fig. 35a), attaining a minimum value of -7°F at t_0 + 16 sec. A pump speed decrease began at about this same time. This performance decrease with increasing fuel turbine internal resistance (percentage pressure drop) indicates probable turbine icing. During a posttest visual inspection, ice accumulation was observed in the fuel turbine; posttest fuel turbine breakaway torque was 400 in.-lb, whereas 25 to 30 in.-lb is normal. A momentary increase of oxidizer turbine internal resistance was observed at approximately t_0 + 16 sec (Fig. 35b); however, oxidizer turbine speed data were not recovered, and it is impossible to relate pump speed with resistance change. A posttest visual inspection indicated no ice formation in the oxidizer turbine.

In an effort to eliminate turbine icing for test period 12, the main oxidizer valve first-stage position was increased from 10 to 11 deg, and a prefire heated gaseous-nitrogen purge was supplied to the turbine. There was no indication that fuel turbine icing developed during firing 12A (Figs 35c and d), but oxidizer turbine icing was evident (Figs 35e and f) From Fig 35e, it can be noted that after transition into high-thrust idle mode, subfreezing temperatures existed inside the oxidizer turbine Also, oxidizer turbine internal resistance exhibited a continuous increase (Fig 35f) throughout the period of oxidizer pump power decay.

Pump performance parameters recorded for firings 12B and 12C (Figs 35g through l) indicated no obvious trends indicative of ice formation. Icing conditions were apparently alleviated for these two firings because of (1) the propellant utilization valve being in null position (open for firing 12A), and (2) higher oxidizer pump inlet pressure (approximately 5 psi) on firings 12B and 12C.

It can be concluded from this series of firings that turbine icing can be expected in high-thrust idle mode anytime inlet temperature approaches water freezing point.

4.4 ENGINE SIDE LOADS

Side loads typical of those recorded during low-thrust idle mode, high-thrust idle mode, and the main-stage mode during the J-2S test firing are presented in Fig. 36. Side load forces generated were generally insignificant; maximum amplitude observed was approximately 500 lbf during transition to main stage.

4.5 ENGINE VIBRATION

Engine vibration data were recorded for each firing discussed in this report. The data revealed that no significant or unusual thrust chamber dome longitudinal vibration was recorded during these firings. Predominant frequencies and maximum acceleration levels encountered during high-thrust idle mode and main-stage operation are tabulated below; however, these frequencies and magnitudes do not represent significant displacement or power level.

Parameter	High-Thrust Predominant Frequencies, Hz	Idle-Mode Maximum Amplitude, g peak to peak	Main-Stage Predominant Frequencies, Hz	Maximum Amplitude, g peak to peak
Oxidizer dome (UTCD-1)	---	---	5400	80
Oxidizer dome (UTCD-2)	---	---	5400	65
Oxidizer dome (UTCD-3)	---	---	5300	65

Fuel pump radial (UFPR)	2500/5300	225	5400/8100	1100
Fuel turbine radial (UFTR)	2600	125	2800/5400/ 8100	500
Oxidizer pump radial (UOPR)	2100	90	2200/7400	500
Thrust chamber throat (UTCT-1)	5200	325	5400/8000	550
Thrust chamber throat (UTCT-2)	1700/2600/ 5300	500	1800/5400/ 8100	600

4.6 TEST ANOMALIES

4.6.1 Engine Damage during Firing 08A

Posttest firing 08A engine inspection revealed that the combustion chamber had been damaged in the region approximately 4 to 5 in. downstream of the injector face. Several of the fuel tubes contained pin-size holes and small cracks (maximum length of separated area was approximately 1.5 in.). The extent of this damage may be seen in Fig 37, which shows postfire photographs taken before the damaged tubes were repaired. Although the photographs show only a portion of the damaged area, the tube damage was evenly distributed around the circumference of the chamber. The damaged tubes were heliarc welded by the engine manufacturer before the next test period; however, thrust chamber leak checks revealed that small tube leaks were still present after the welding was performed. The thrust chamber had also been damaged during previous testing and repaired by the engine manufacturer before delivery to AEDC.

4.6.2 Main-Stage Operation during Firing 12A

Main-stage operation during firing 12A was an unexpected occurrence. Before firing 12A the main-stage control timer had been set so that the main-stage control solenoid would be energized 15.0 sec after the main-stage start signal. The main-stage control timer consisted of a 10-sec facility timer in combination with a 5-sec engine timer located inside the electrical control assembly. Prefire engine sequence checks verified that the timer had been set correctly. However, during the firing, the timer expired early at 12.7 sec, thus commanding the engine into main-stage operation. After 1.7 sec of main-stage operation, an automatic cutoff occurs if oxidizer injector pressure has not attained a minimum value of 650 ± 15 psia. Chamber pressure had attained a value of only 552 psia after 1.7 sec, resulting in the engine cutoff. The early expiration of the timer combination is believed to have been the result of environmental effects during the engine firings on the 5-sec timer located inside the electrical control assembly on the engine. The facility timer is located outside the test cell and not subject to these influences.

4.6.3 Oxidizer Pump Inlet Fluid Prerotation

Firing 12B was terminated prematurely by an observer cutoff when oxidizer pump inlet static pressure exceeded established redline limits (Fig. 38). Postfire analysis of the pump inlet pressure data revealed that after approximately 2.4 sec of high-thrust idle-mode operation, an increase in indicated oxidizer pump inlet static pressure occurred. A 4-psi static pressure increase occurred over a time period of approximately 1.5 sec. The pump inlet pressure remained at this new pressure level throughout the remainder of high-thrust idle-mode operation. Research of oxidizer pump inlet pressure data on high-thrust idle-mode firings revealed that this phenomenon had, in fact, occurred on all of these firings and was repeatable. However, at the initiation of main-stage operation, the pump inlet pressure data indicated a pressure drop to a value normally expected (Fig. 38).

The pump inlet pressure increase is a result of prerotation of the liquid oxygen as it prepares to enter the impeller. Stepanoff (Ref. 6) explains that prerotation is encountered in a centrifugal pump operating at below-design flow rates and that prerotation disappears as the pump approaches design flow rate. Assuming that the pressure difference, during high-thrust idle mode, between oxidizer ullage tank pressure and oxidizer pump inlet pressure is caused by a combination of static head, dynamic pressure, friction losses, and prerotation, then prerotation at the rate of approximately 340 rpm would produce the changes in indicated pump inlet pressure shown above.

SECTION V
SUMMARY OF RESULTS

Three test periods were conducted on April 2, May 6, and May 9, 1969, to evaluate the J-2S engine operating characteristics during transition from low-thrust idle mode to high-thrust idle mode (50,000 lbf) and from high-thrust idle mode to main stage. The results of these tests are summarized as follows:

1. The initial attempt to transition the J-2S engine from low-thrust to high-thrust idle mode (firing 08A) was terminated prematurely after 4.4 sec because of excessive hot gas tapoff manifold temperatures. Subsequent transitions from low-thrust to high-thrust idle mode were successfully demonstrated on firings 11A, 12A, 12B, and 12C.

2. The J-2S engine was successfully transitioned from high-thrust idle mode to main-stage operation during firing 12C.

3. Fuel turbine icing problems were noted during high-thrust idle-mode operation on firings 11A and 12A. As a result of ice formation in the fuel turbine assembly, the pump did not rotate during firing 11B, and a performance decay was noted during high-thrust idle mode on firing 12A.

4. Side forces generated during these tests were generally insignificant; maximum amplitude observed was approximately 500 lbf during transition to main-stage operation.

5. No significant or unusual thrust chamber dome longitudinal vibration was recorded. Vibration recorded at other points on the engine did not produce either significant displacement or power level

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1. Dubin, M., Sissenwine, N., and Wexler, H. (Ed.). U. S. Standard Atmosphere, 1962 December 1962.

2. Muse, W. W. and Kunz, C. H. "Altitude Developmental Testing of the J-2S Rocket Engine in Propulsion Engine Test Cell (J-4) (Tests J4-1902-05 through J4-1902-07)." AEDC-TR-70- (to be published).

3. Collier, M. R. and Pillow, C. E. "Altitude Developmental Testing of the J-2S Rocket Engine in Propulsion Engine Test Cell (J-4) (Tests J4-1902-09 and J4-1902-10)." AEDC-TR-70- (to be published).

4. "J-2S Interface Criteria." Rocketdyne Document J-7211, October 16, 1967.

5. Test Facilities Handbook (Eighth Edition). "Large Rocket Facility, Vol. 3." Arnold Engineering Development Center, December 1969.

6. Stepanoff, A. J. Centrifugal and Axial Flow Pumps: Theory, Design, and Application. (Second Edition), John Wiley and Sons, Inc., 1957.

APPENDIXES

I. ILLUSTRATIONS
II. TABLES
III. INSTRUMENTATION

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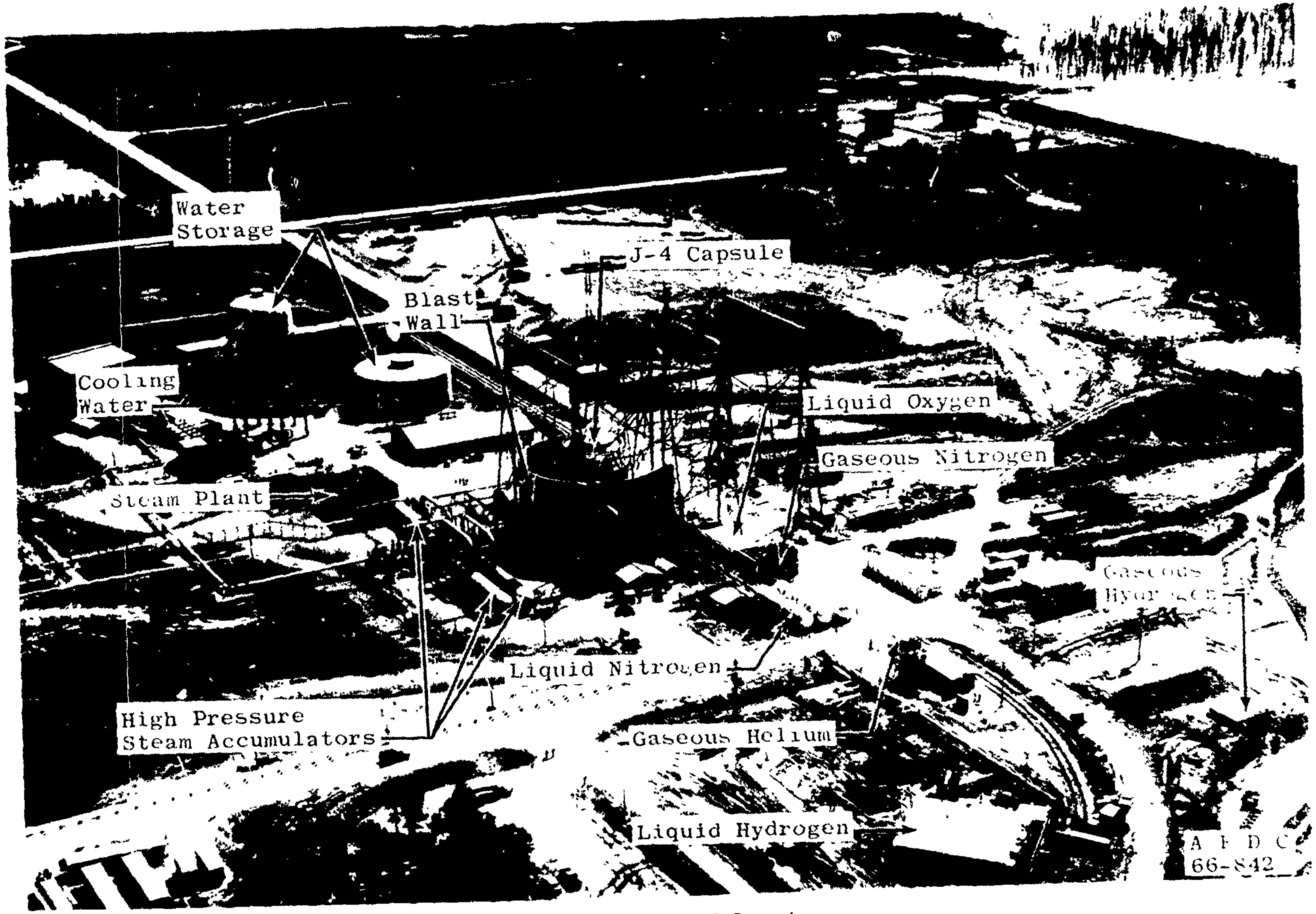


Fig. 1 Test Cell J-4 Complex

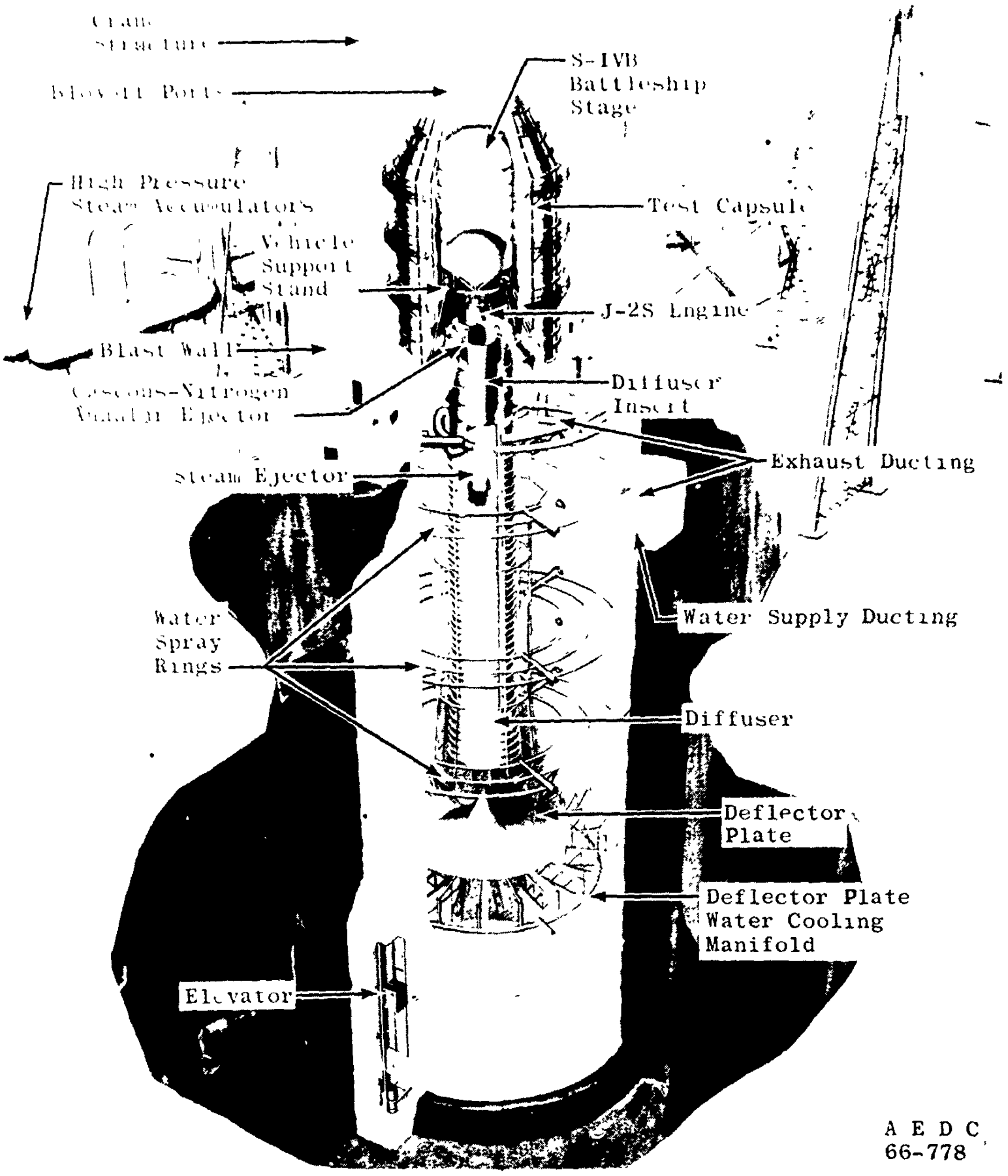


Fig. 2 Test Cell J-4, Artist's Conception

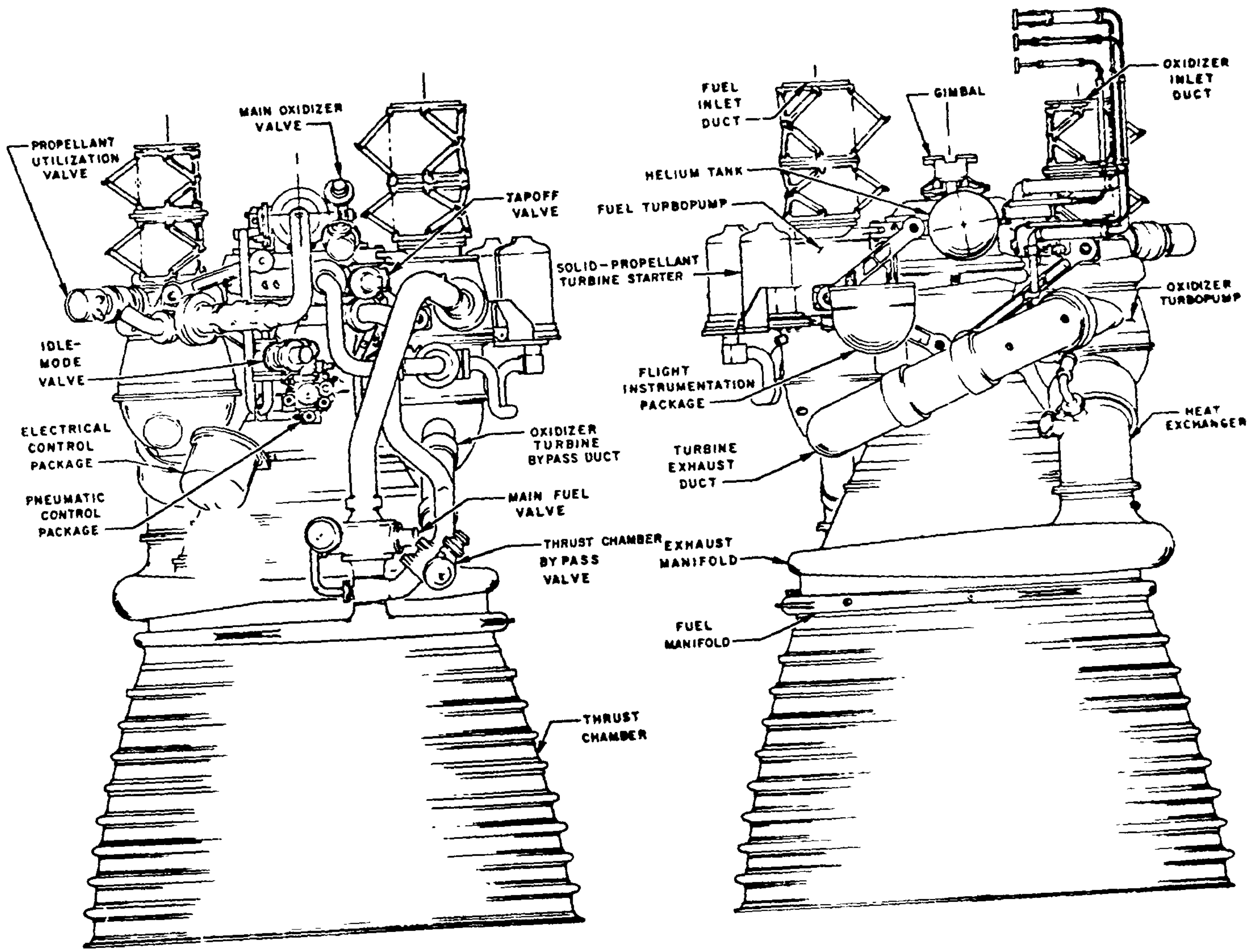


Fig. 3 J-2S Engine, General Arrangement

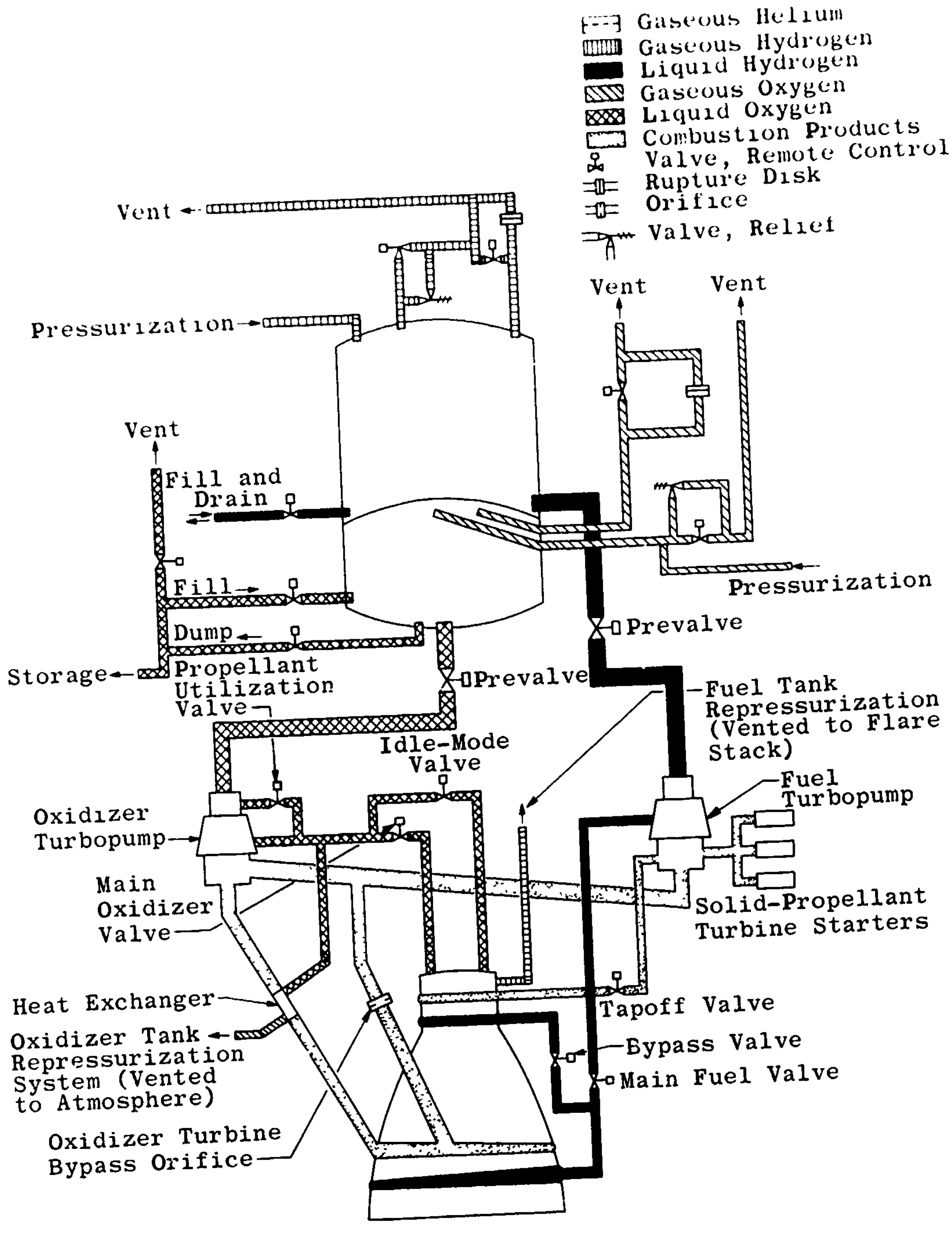
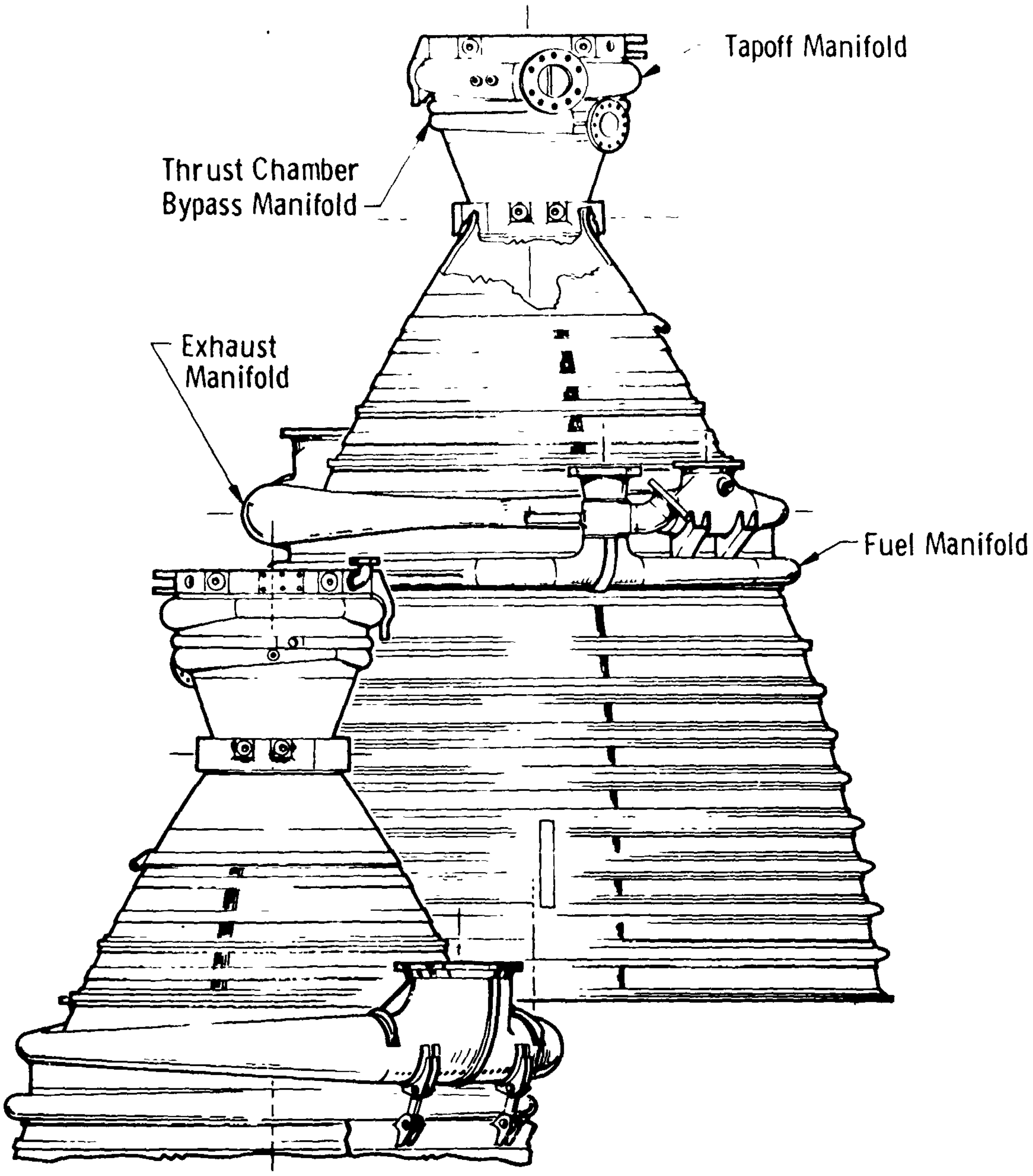
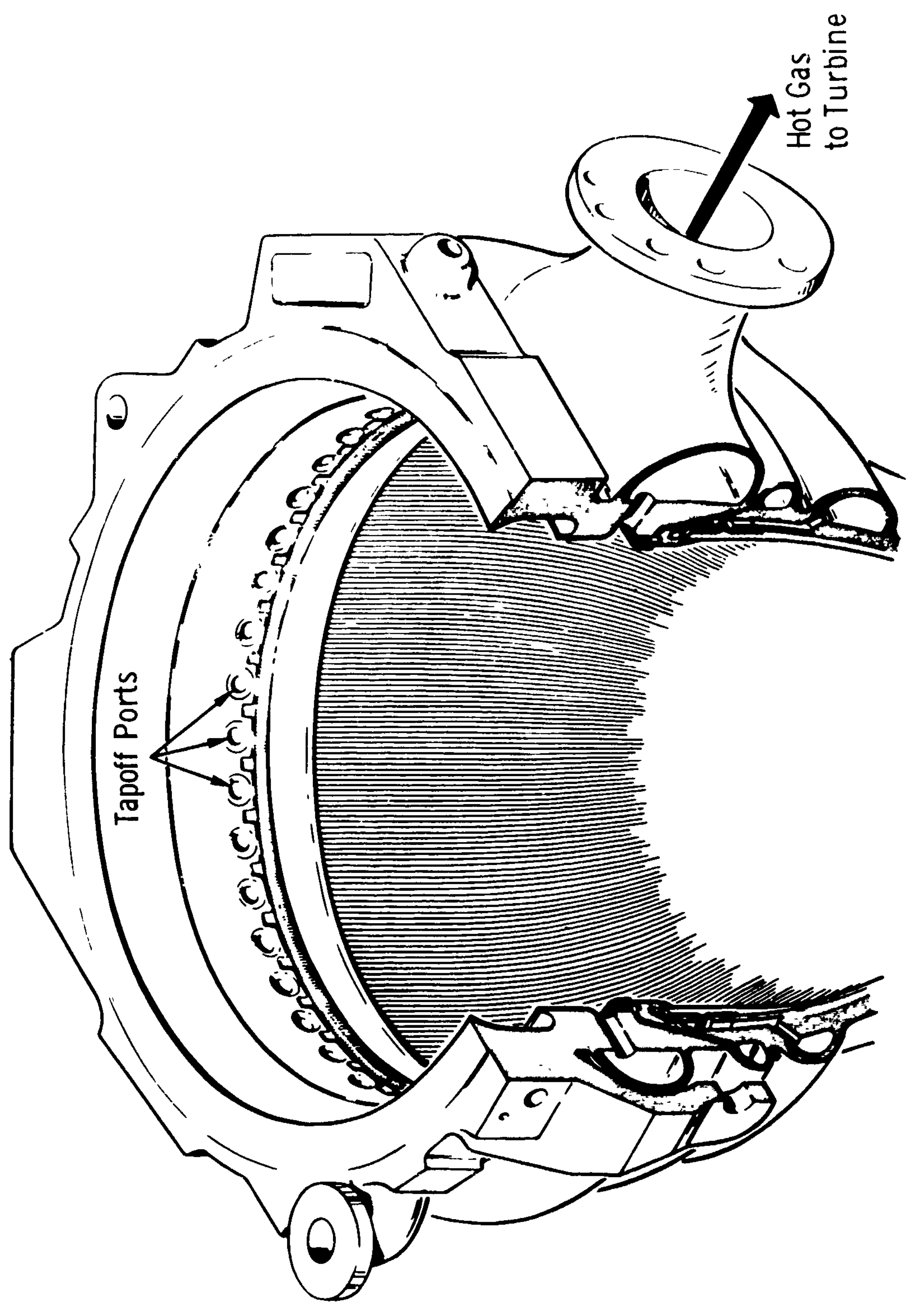


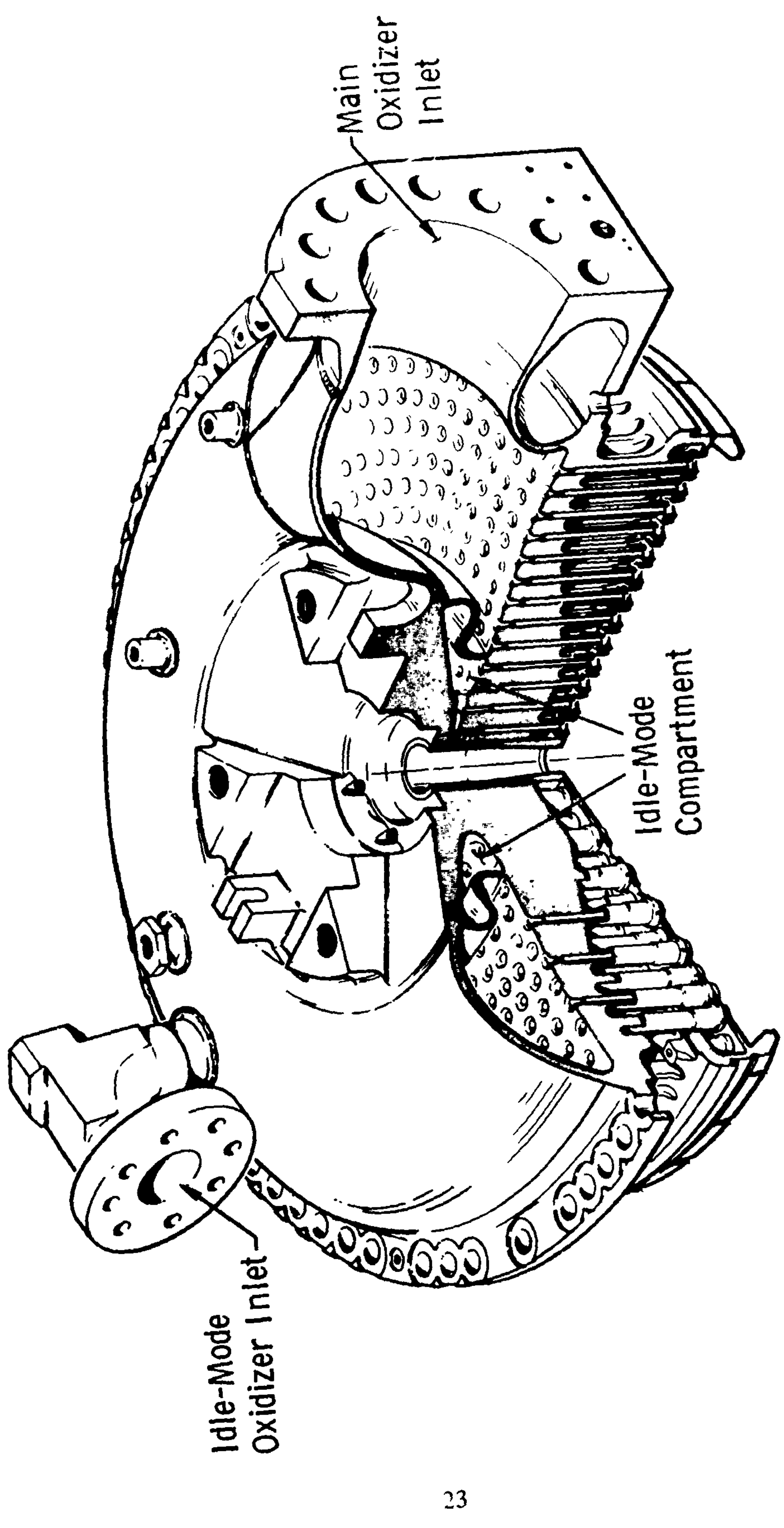
Fig. 4 S-IVB Battleship Stage/J-2S Engine Schematic



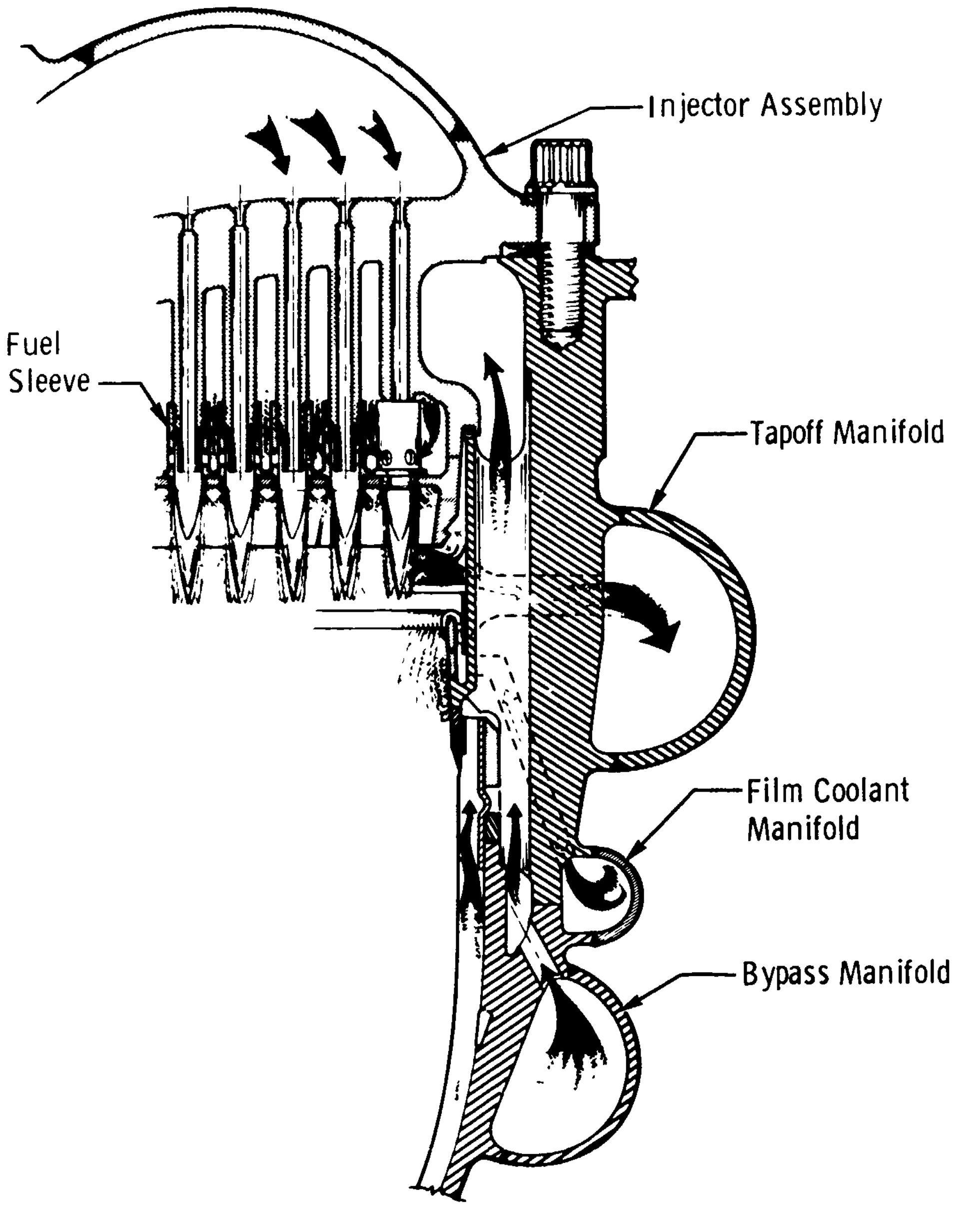
a. Thrust Chamber
Fig. 5 Engine Details



b. Combustion Chamber
Fig. 5 Continued



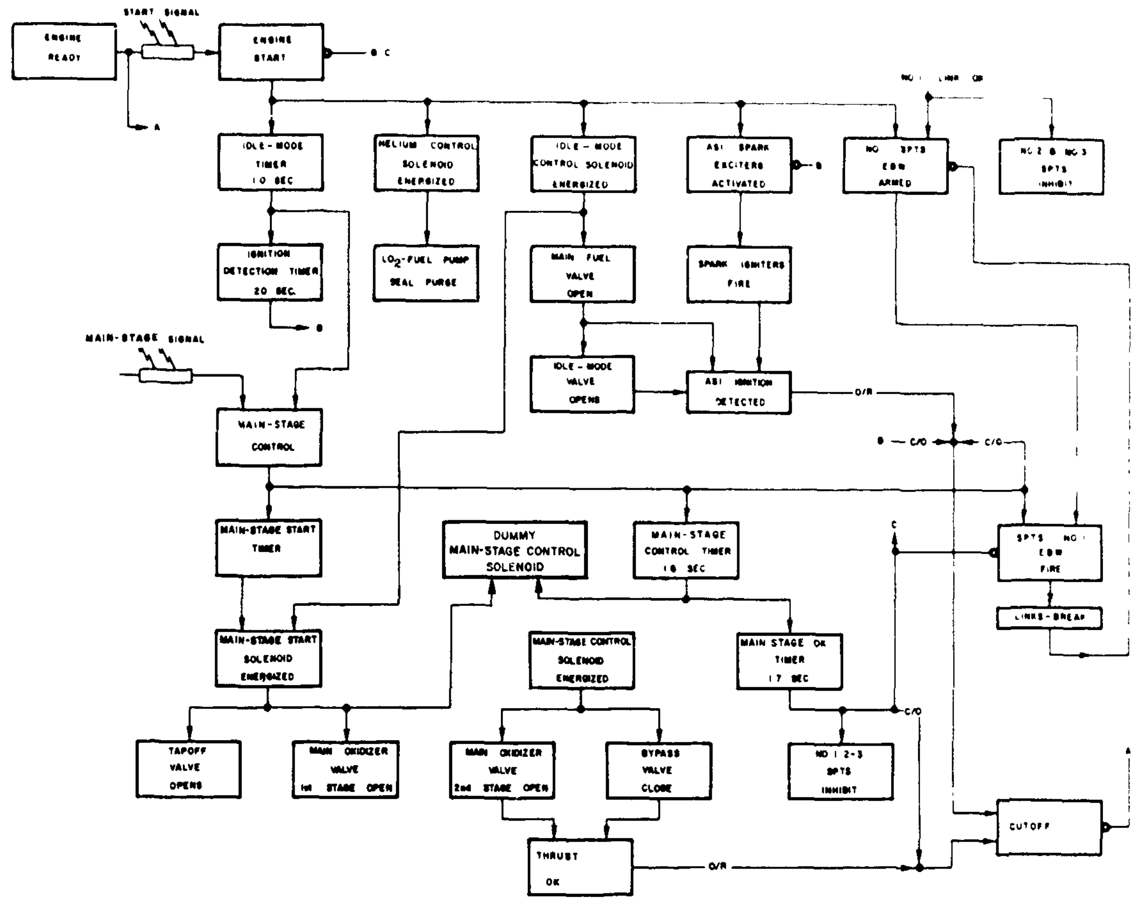
c. Injector
Fig. 5 Continued



d. Injector to Chamber
Fig. 5 Concluded

Notes: 1. The fuel bypass valve was manually operated on test periods 08 and 11.

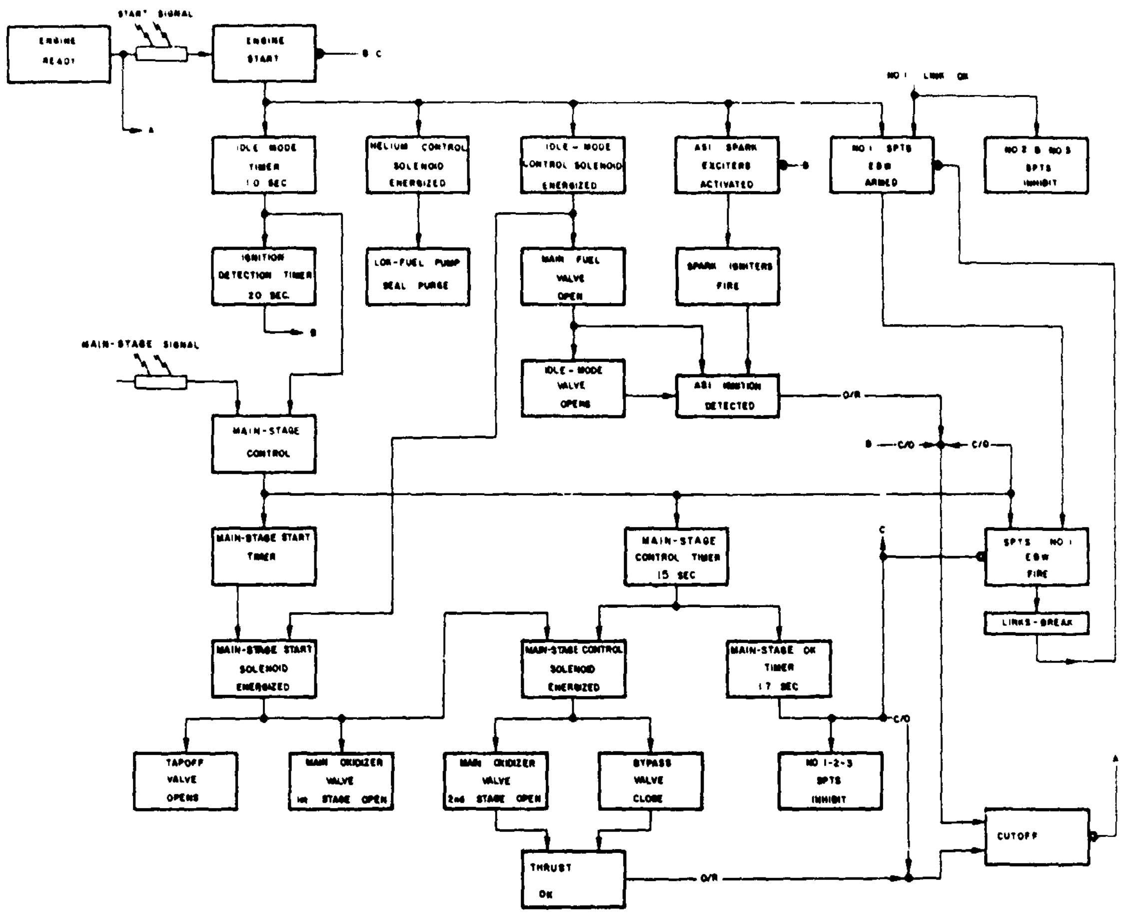
2. Thrust "OK" signal was simulated on test periods 08 and 11.



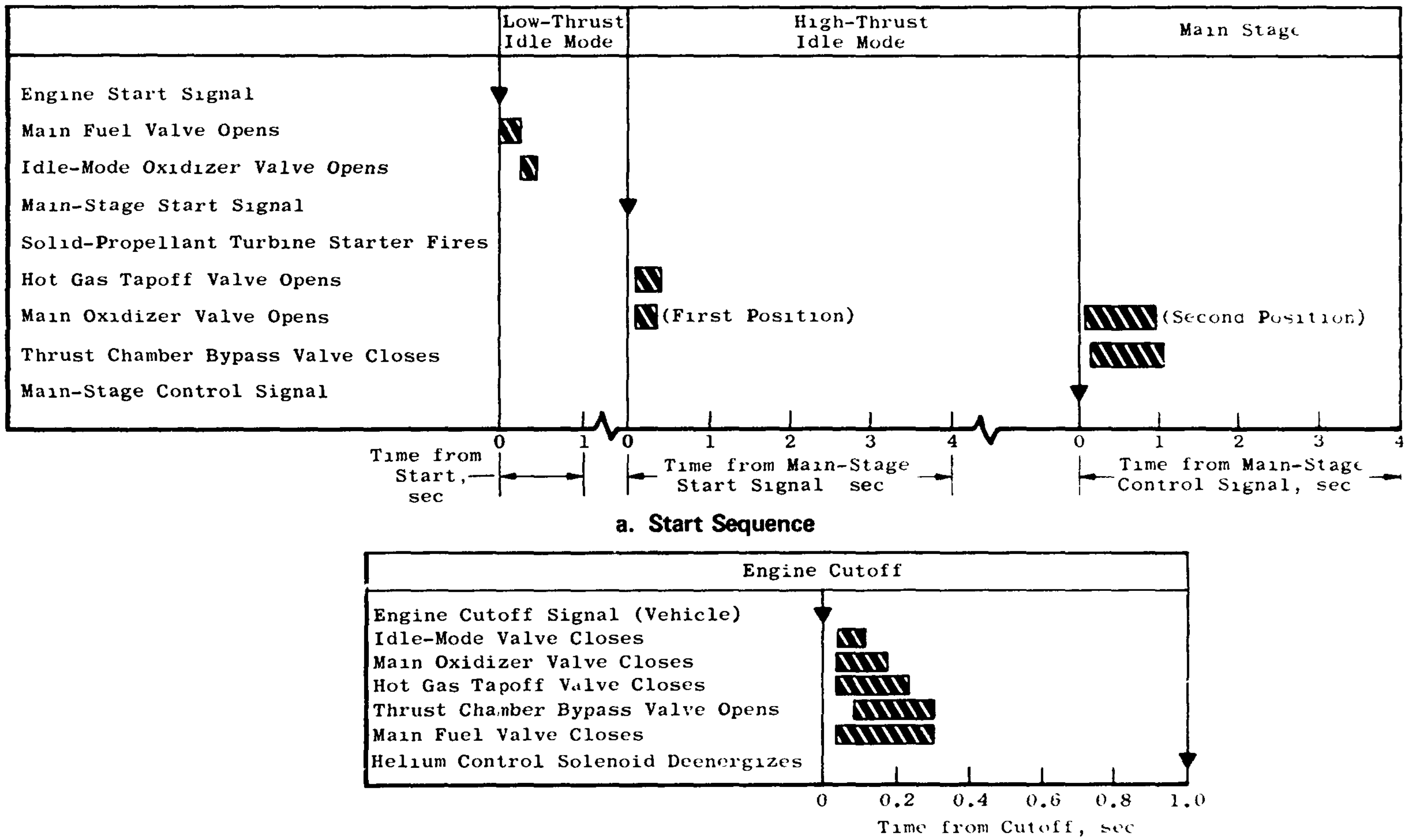
a. Test Periods 08 and 11

Fig. 6 Engine Start Logic Schematic

Note: Thrust "OK" signal was simulated on test period 12.



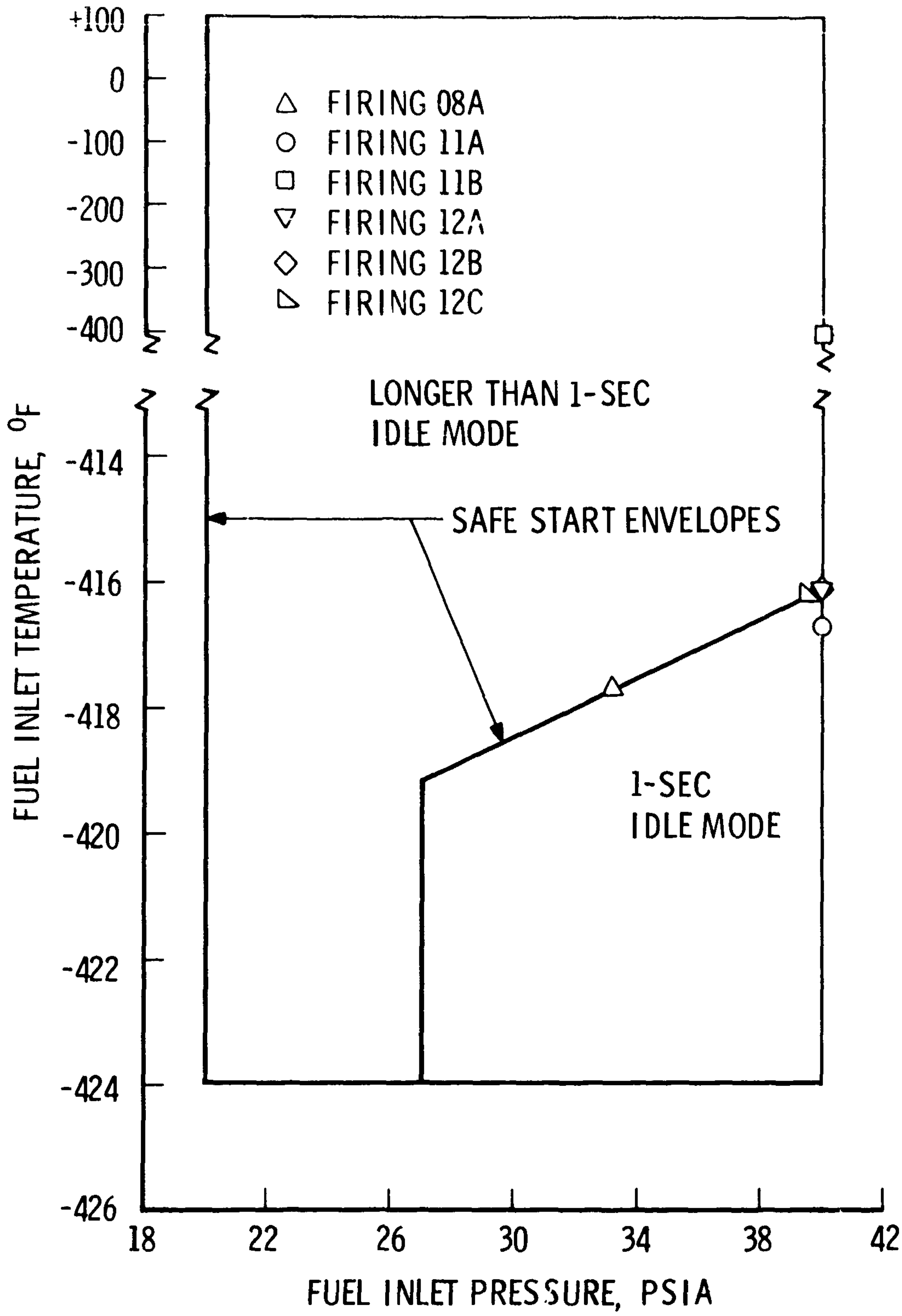
b. Test Period 12
Fig. 6 Concluded



a. Start Sequence

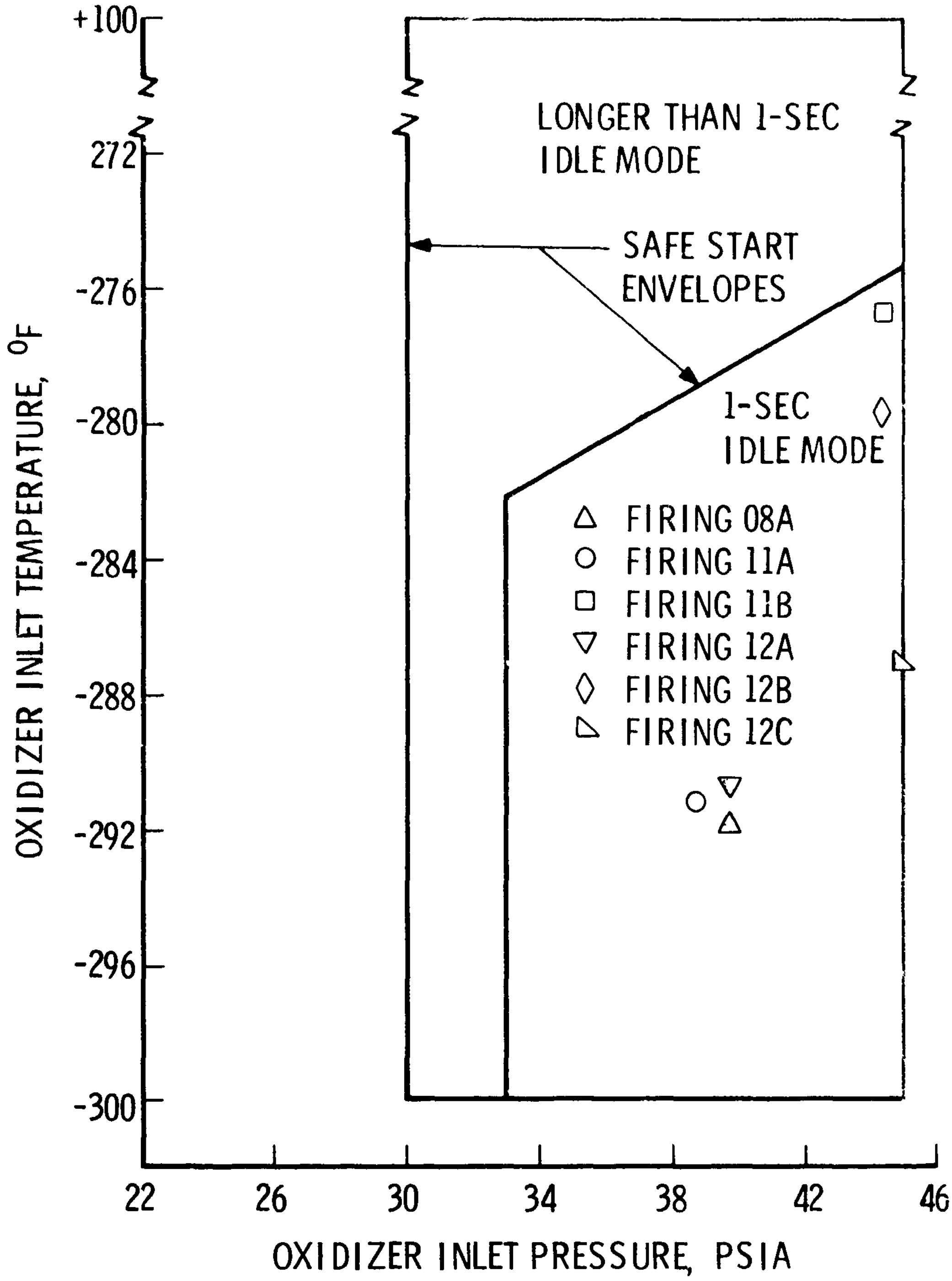
b. Shutdown Sequence

Fig. 7 Engine Start and Shutdown Sequence

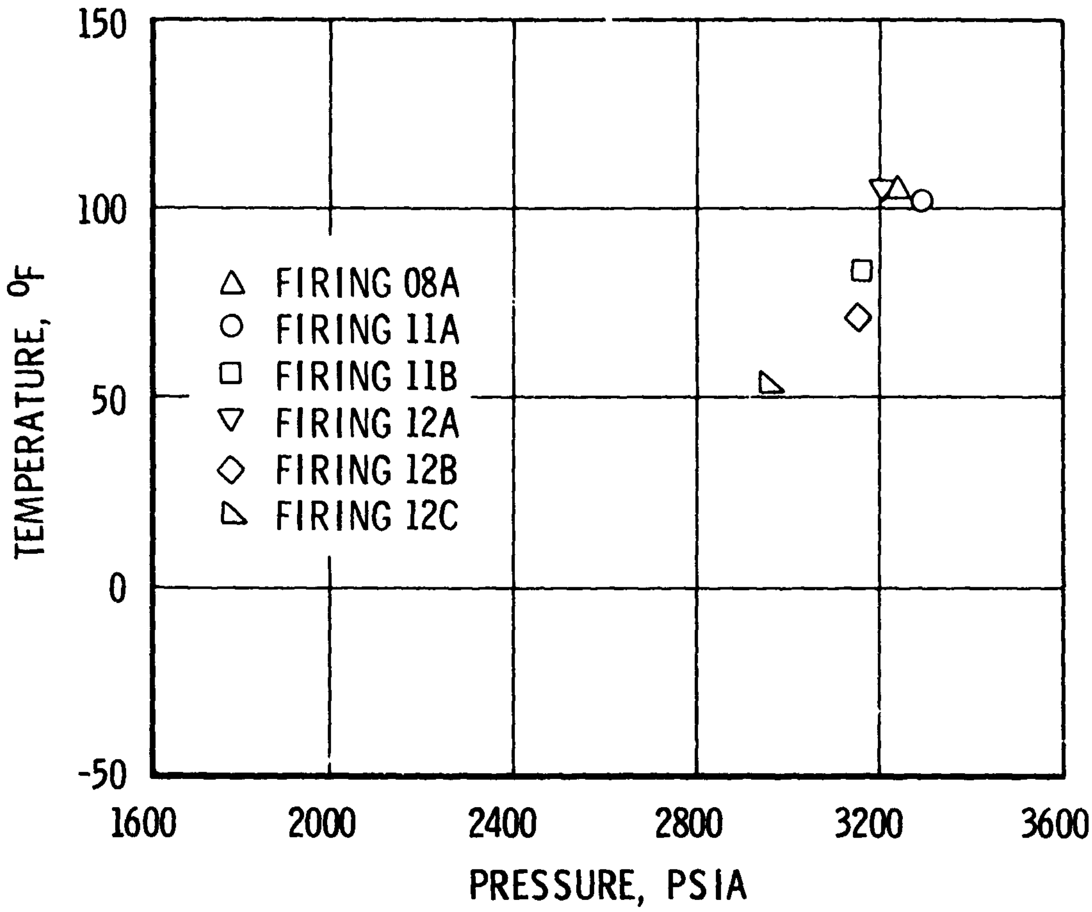


a. Fuel Pump

Fig. 8 Engine Start Conditions for Propellant Pump Inlets and Helium Tank



b. Oxidizer Pump
Fig. 8 Continued



c. Helium Tank
Fig. 8 Concluded

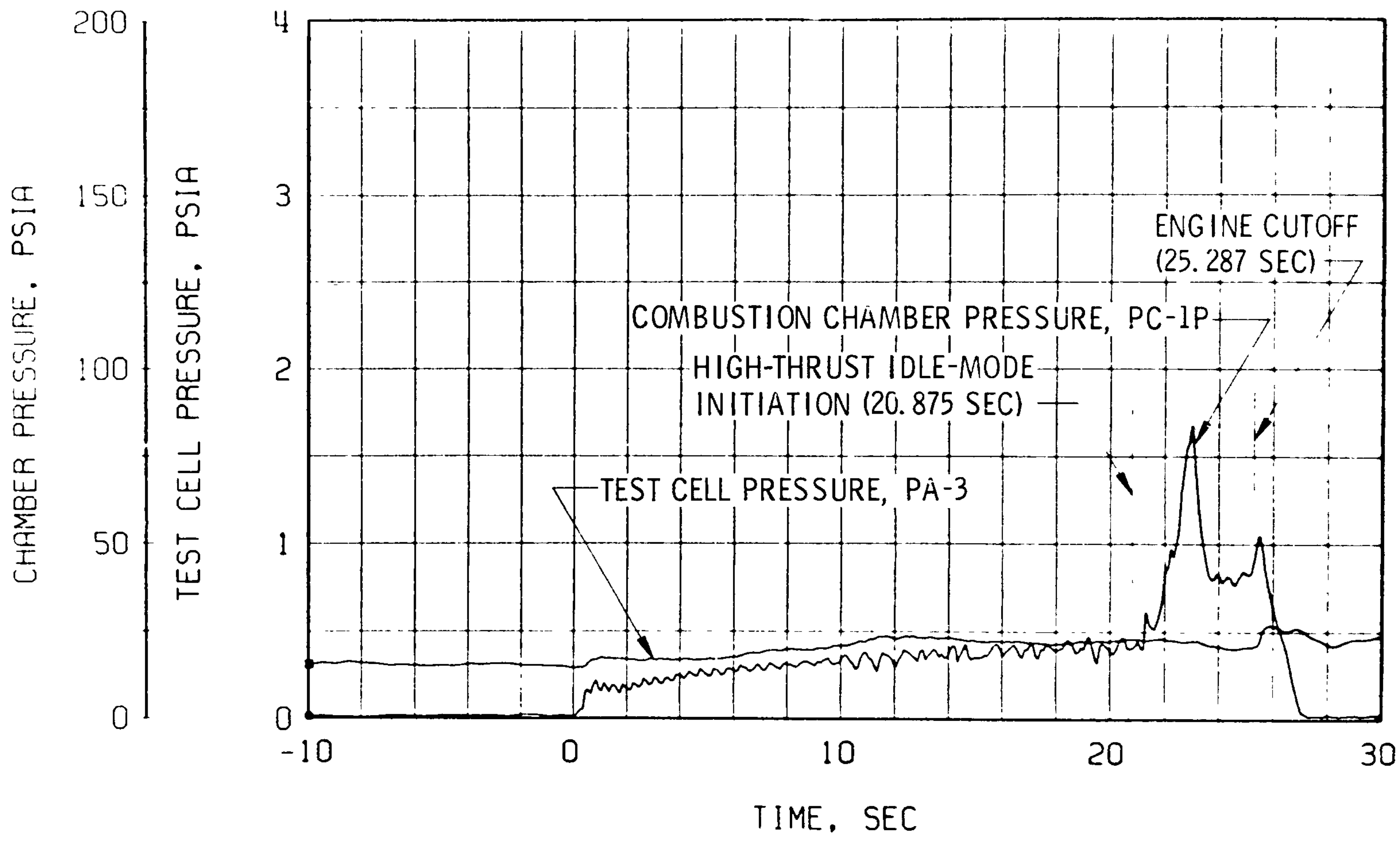


Fig. 9 Engine Ambient and Combustion Chamber Pressure, Firing 08A

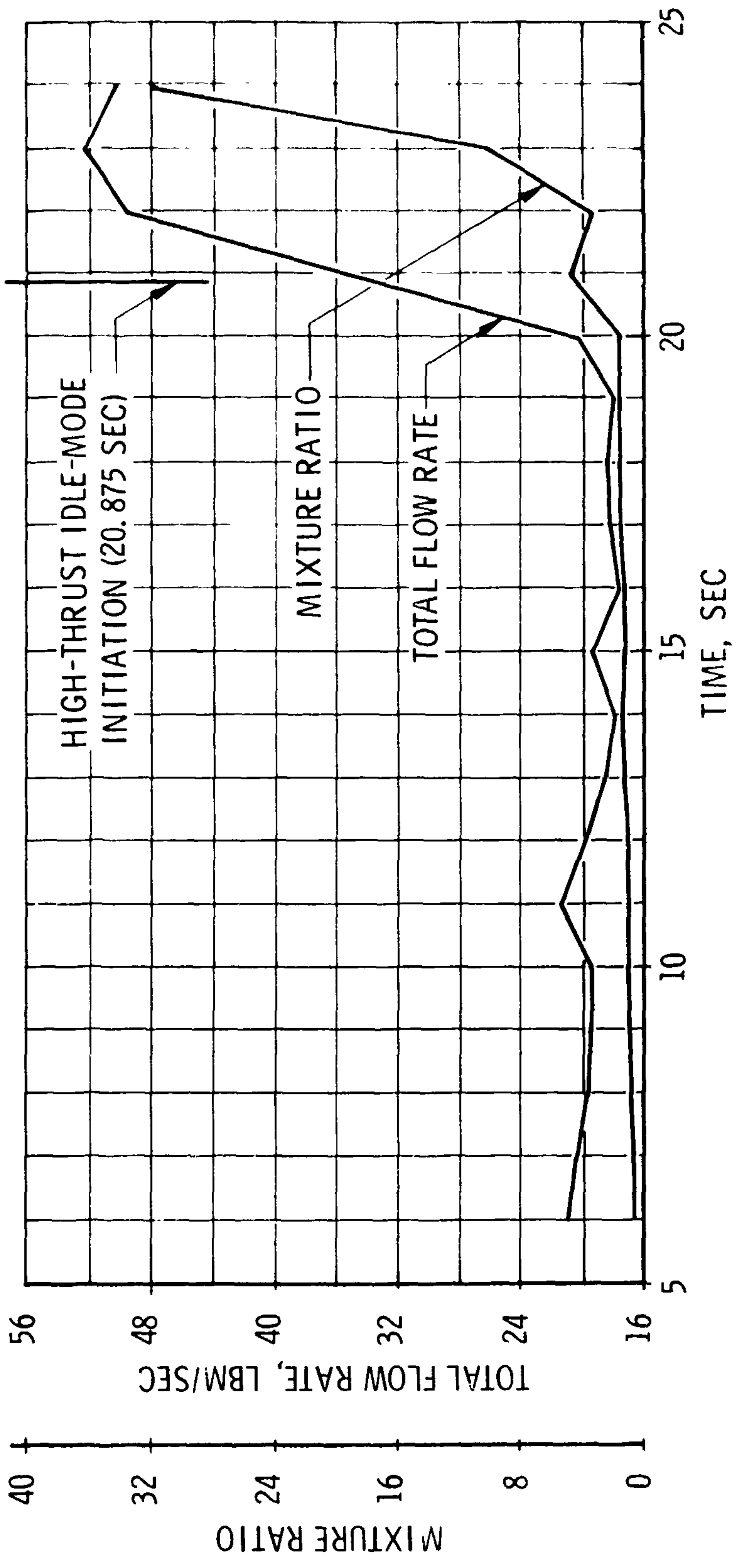
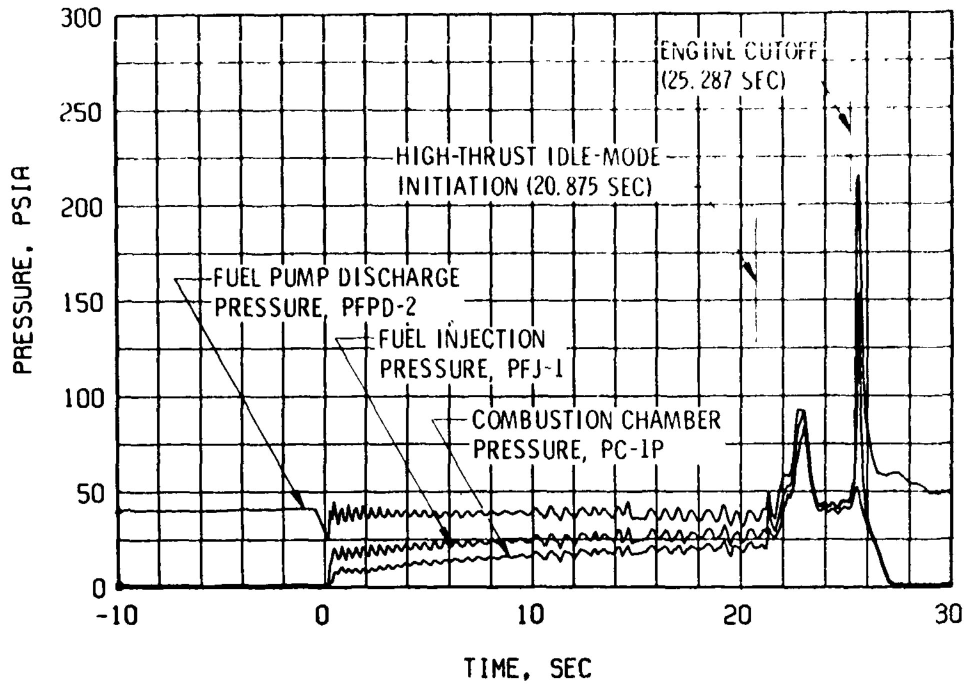
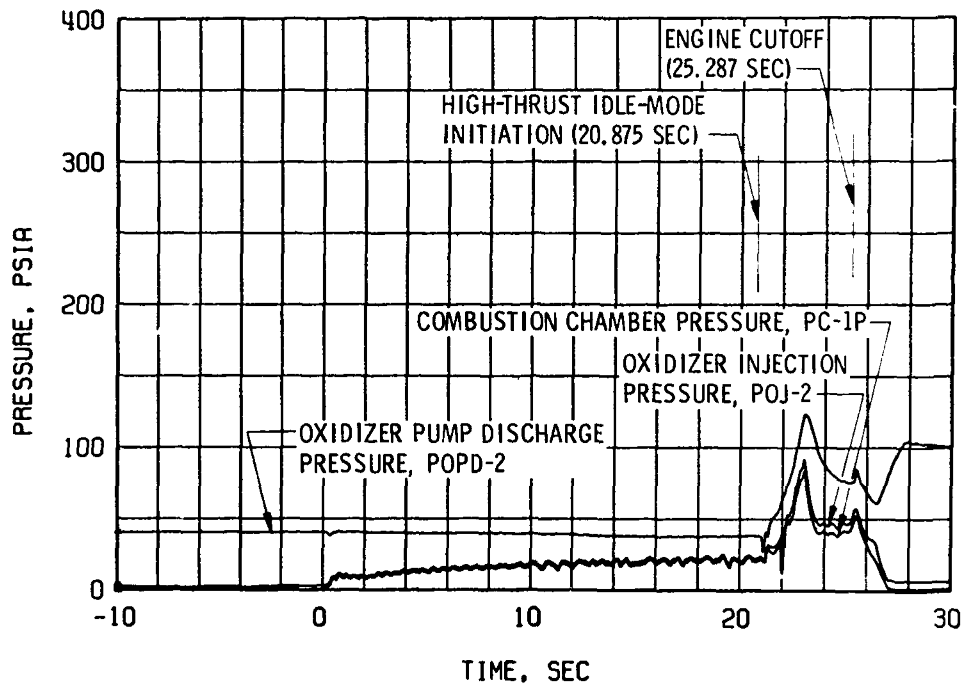


Fig. 10 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 08A



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge, Oxidizer Injection, and Combustion Chamber Pressure

Fig. 11 Propellant System Performance, Firing 08A

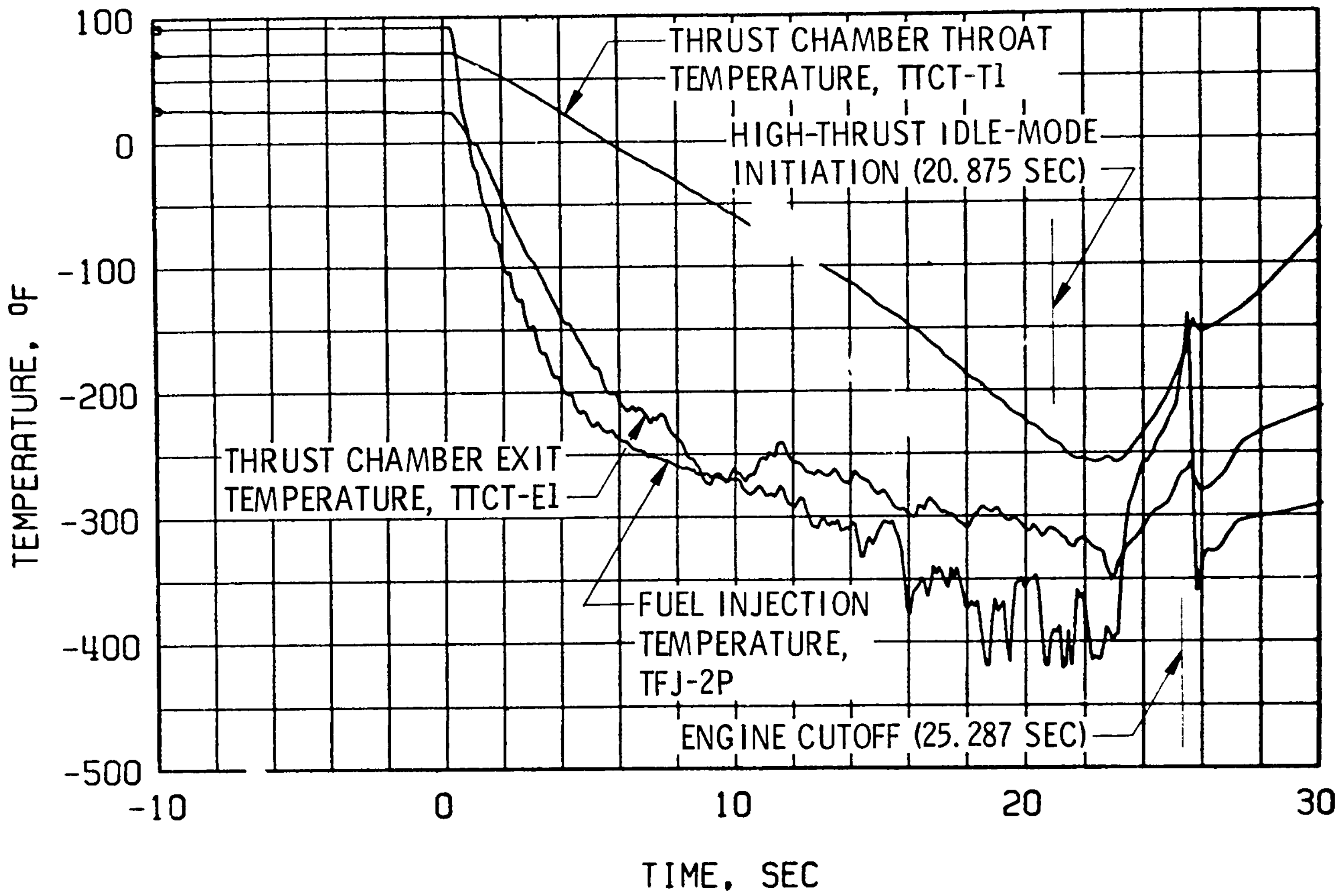


Fig. 12 Thrust Chamber Chilldown and Fuel Injection Temperature, Firing 08A

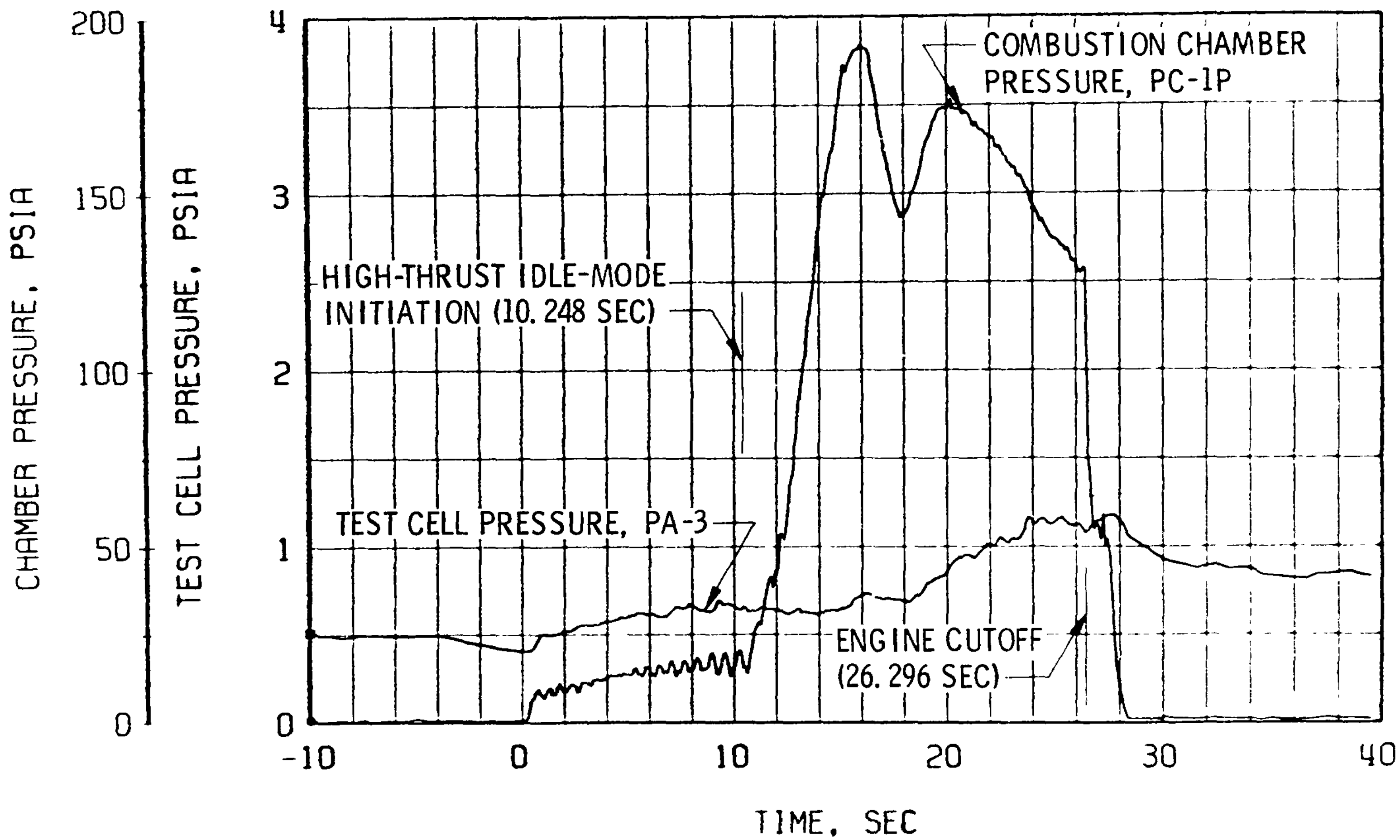


Fig. 13 Engine Ambient and Combustion Chamber Pressure, Firing 11A

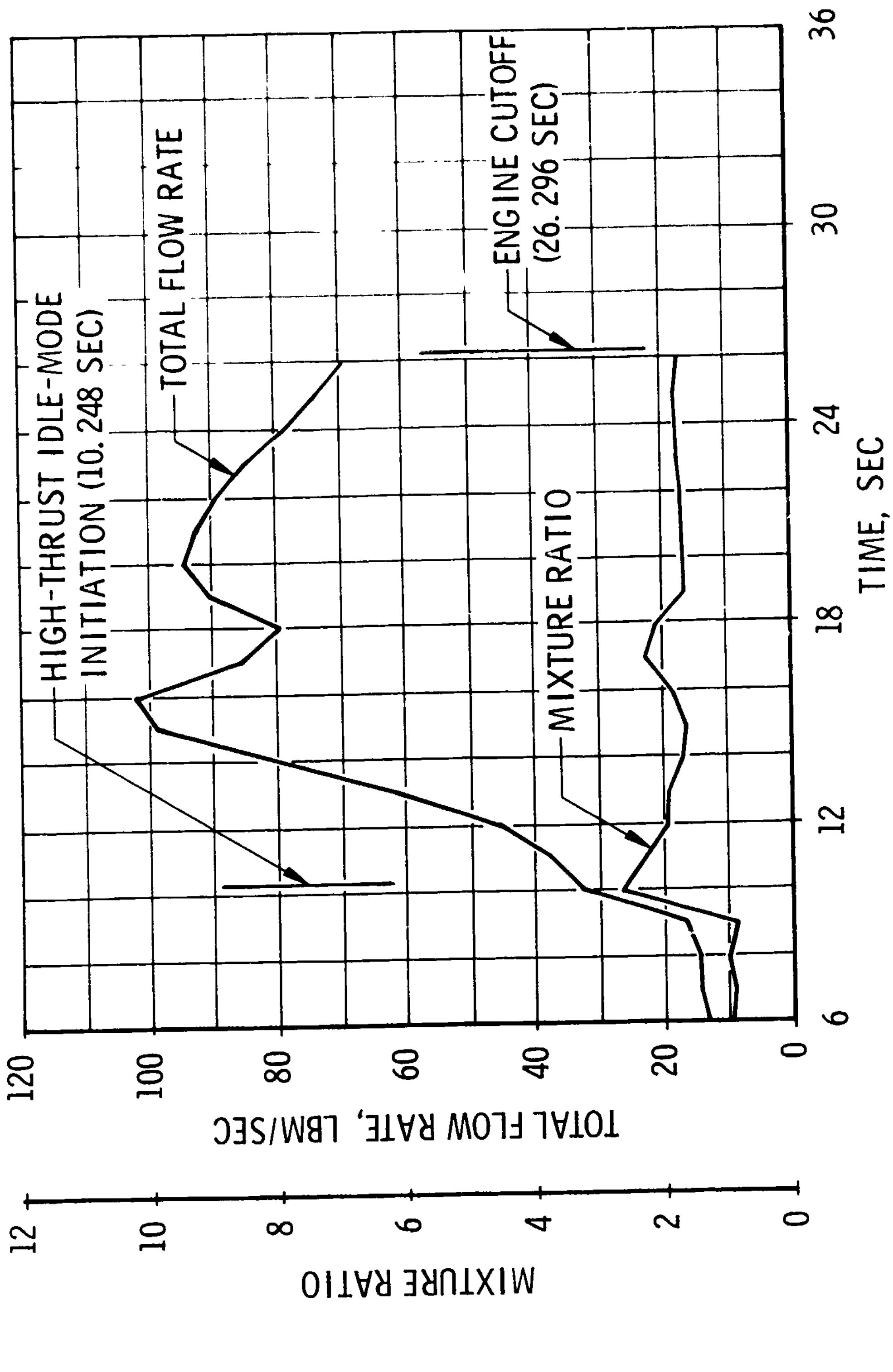
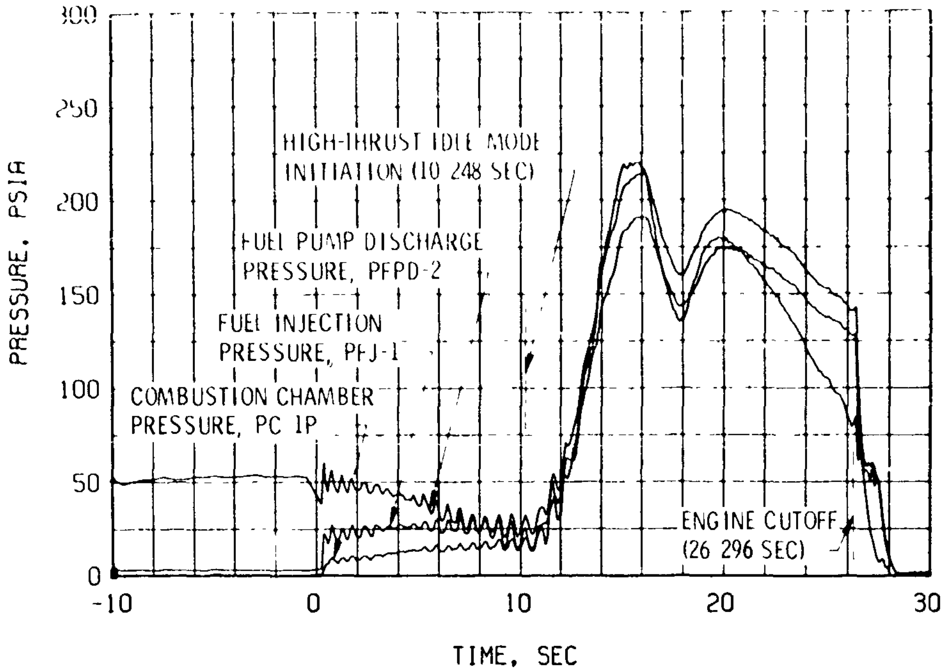
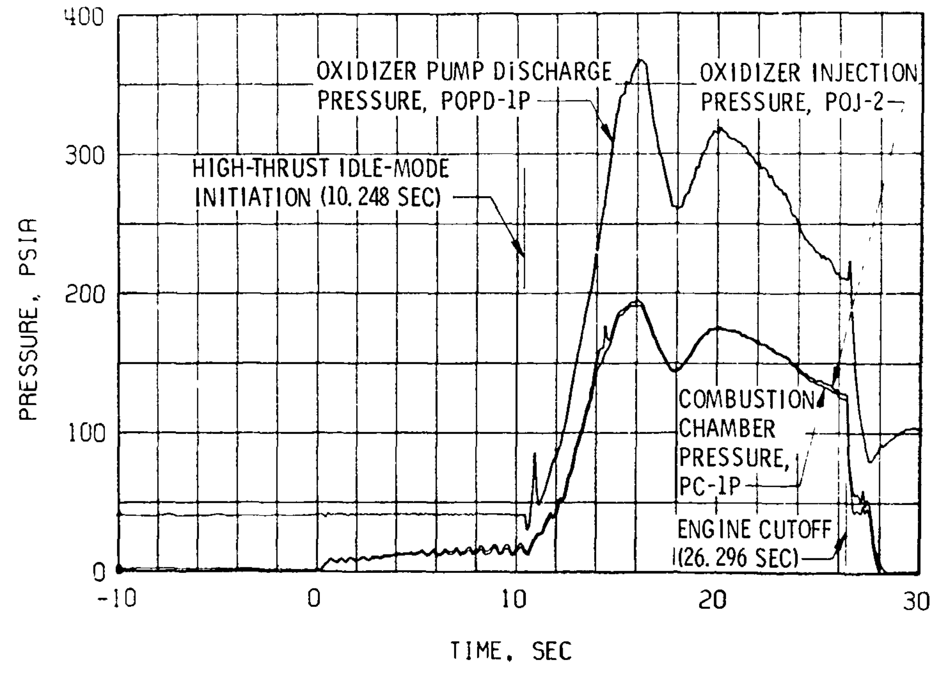


Fig. 14 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 11A



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge Oxidizer Injection and Combustion Chamber Pressure
Fig. 15 Propellant System Performance, Firing 11A

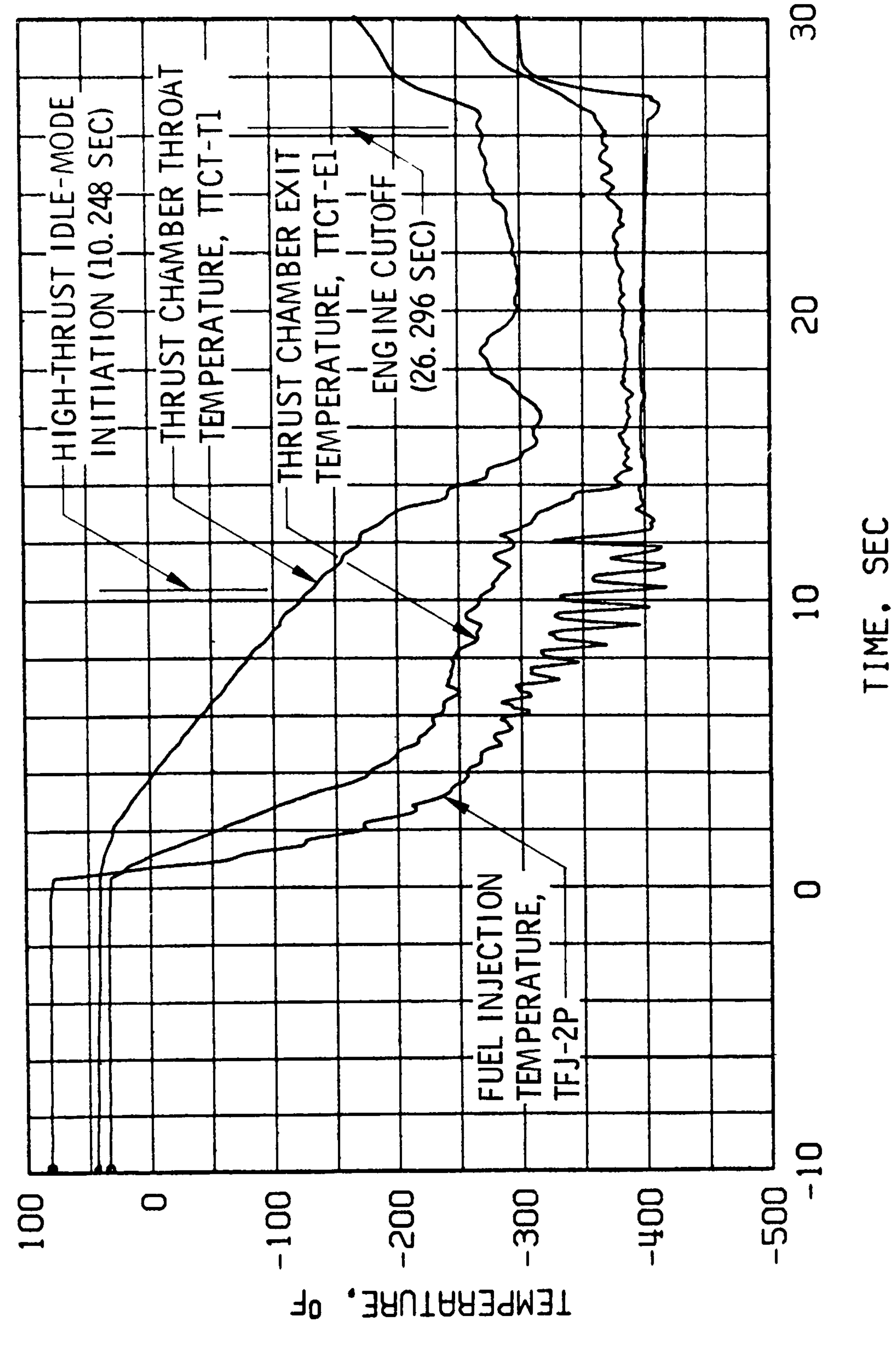


Fig. 16 Thrust Chamber Chilldown and Fuel Injection Temperature, Firing 11A

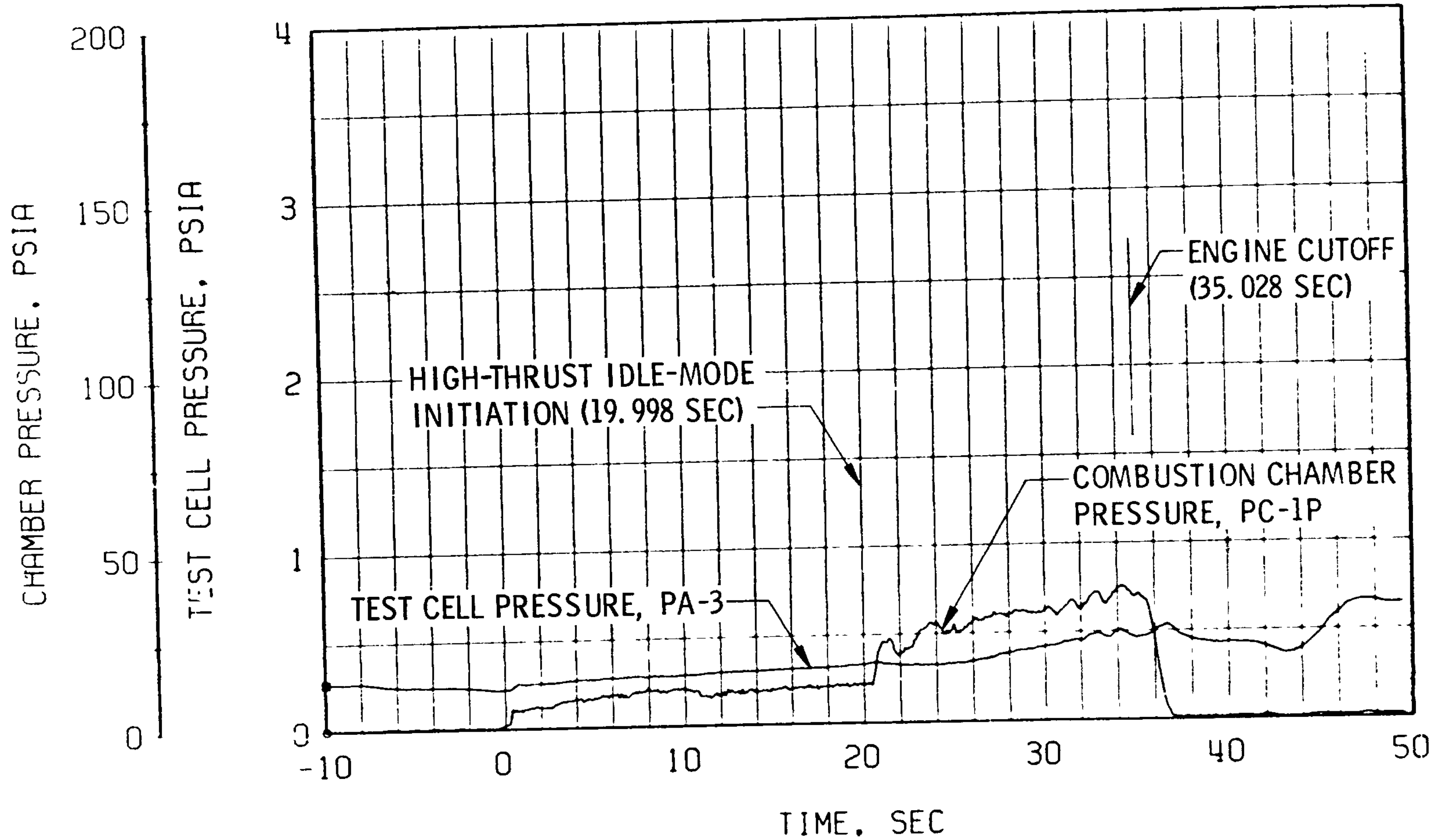


Fig. 17 Engine Ambient and Combustion Chamber Pressure, Firing 11B

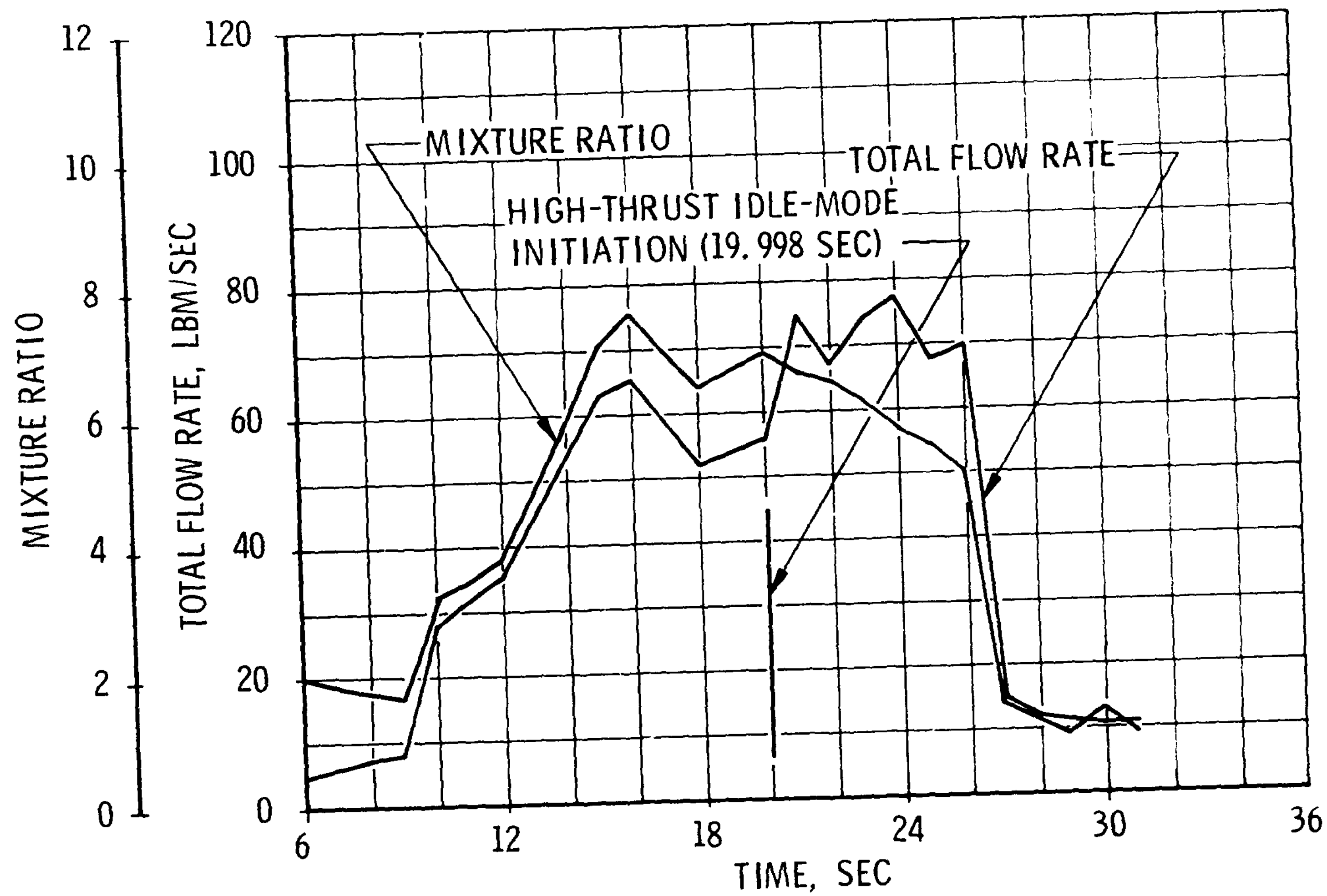
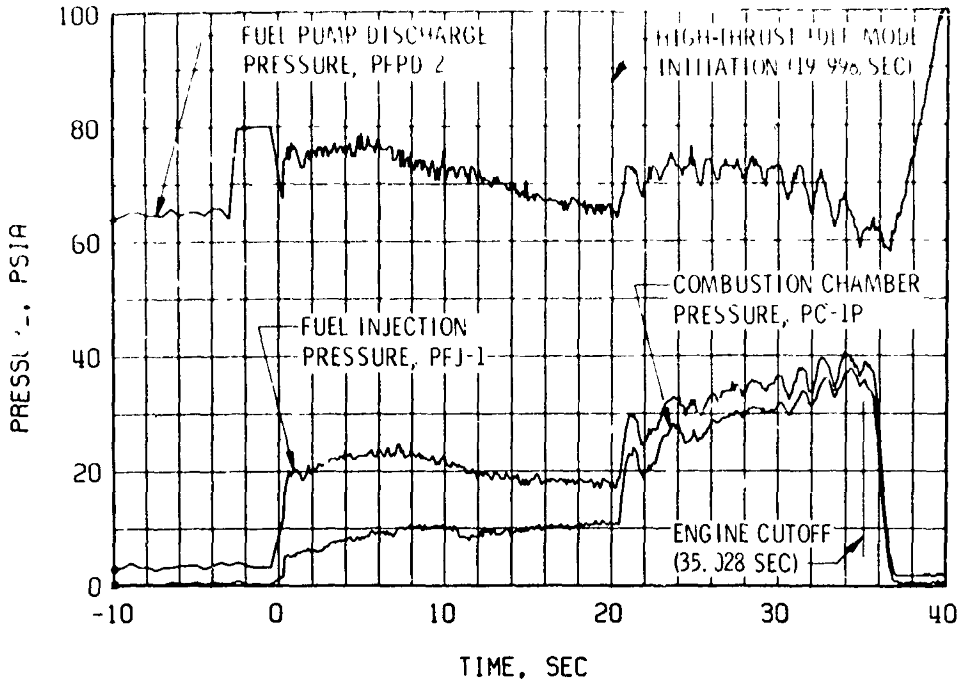
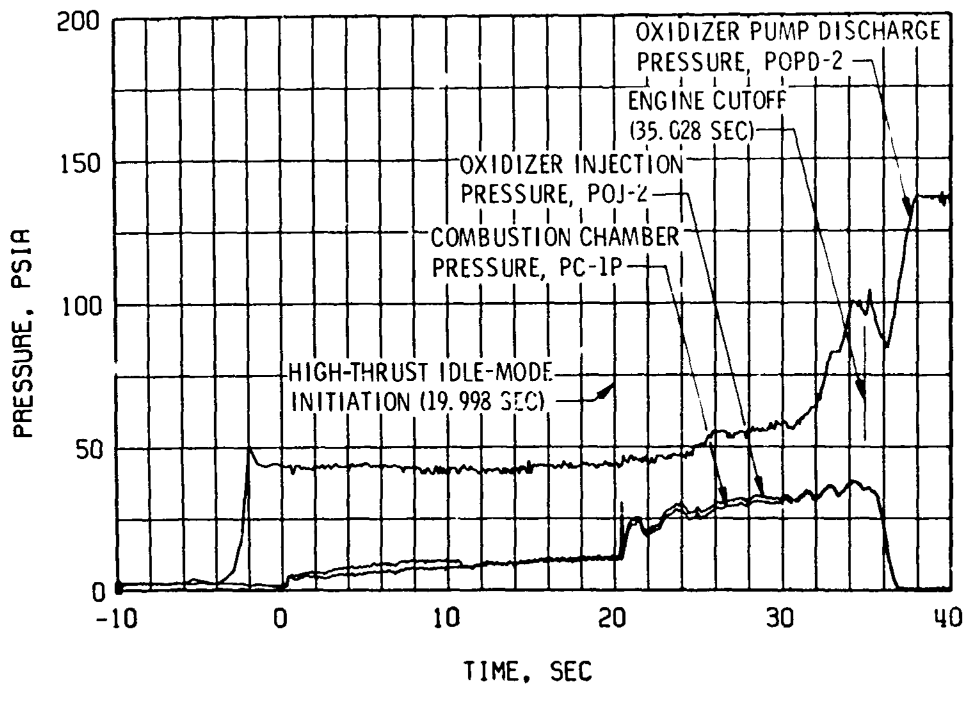


Fig. 18 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 11B



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge, Oxidizer Injection, and Combustion Chamber Pressure

Fig. 19 Propellant System Performance, Firing 11B

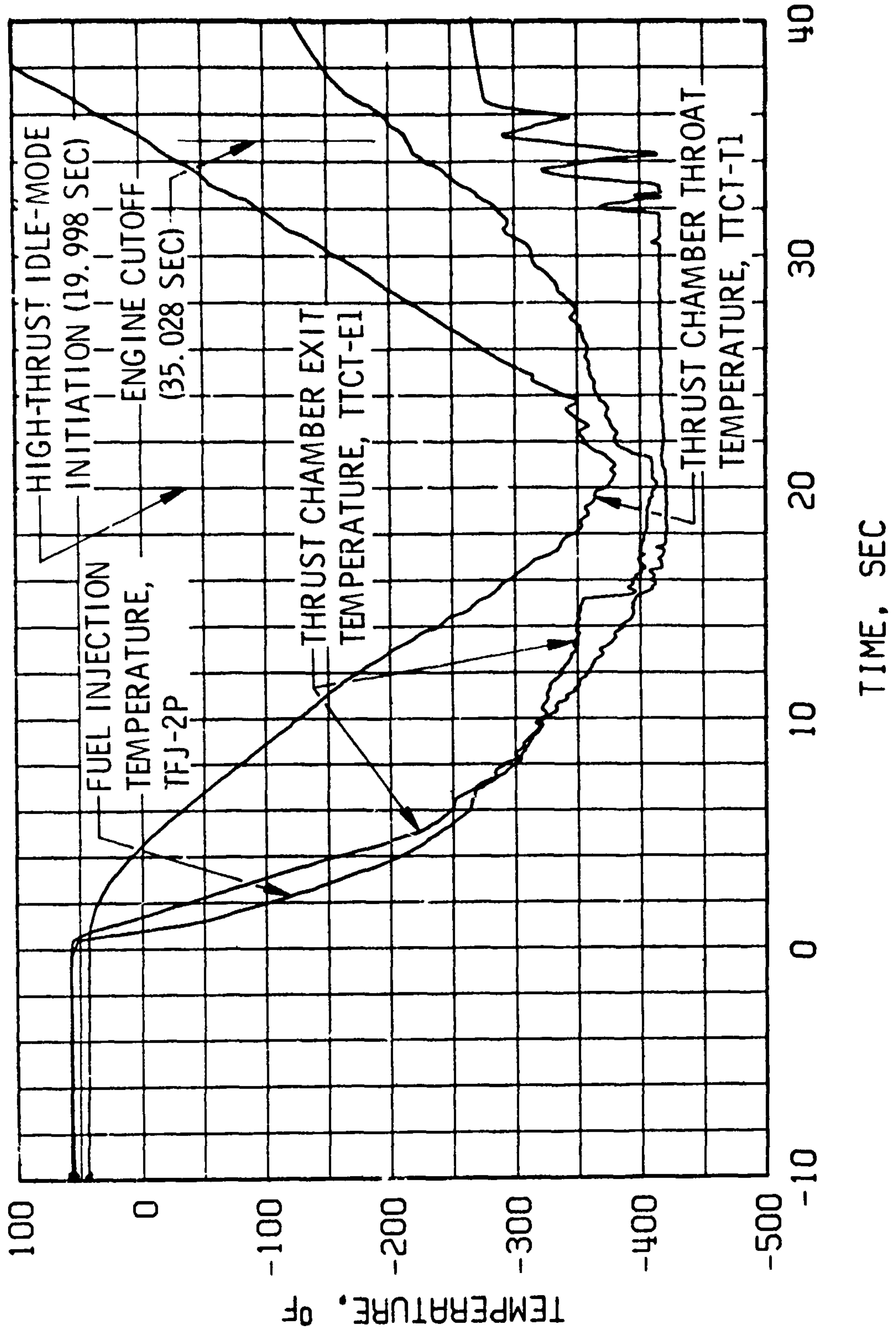


Fig. 20 Thrust Chamber Chilldown and Fuel Injection Temperature, Firing 11B

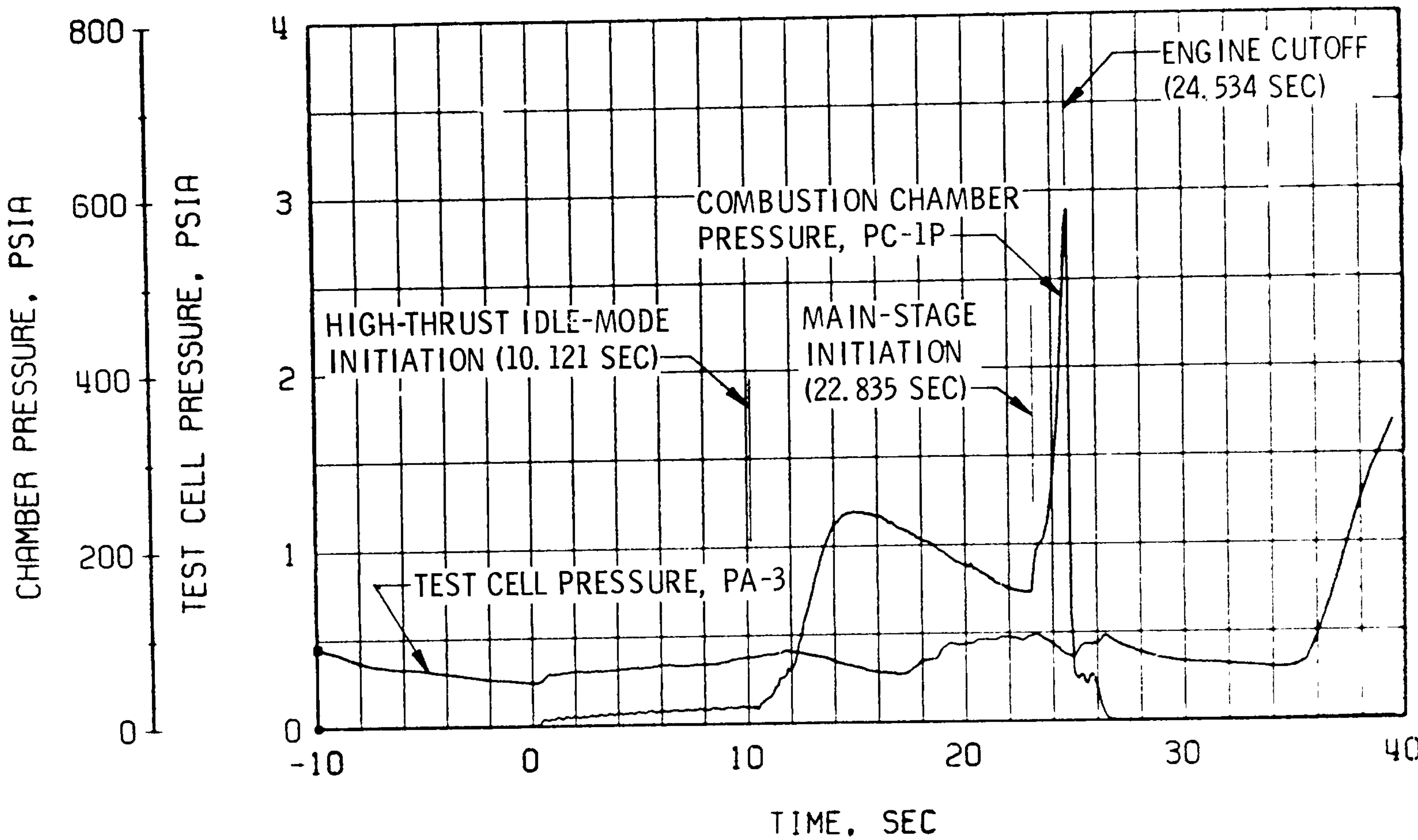


Fig. 21 Engine Ambient and Combustion Chamber Pressure, Firing 12A

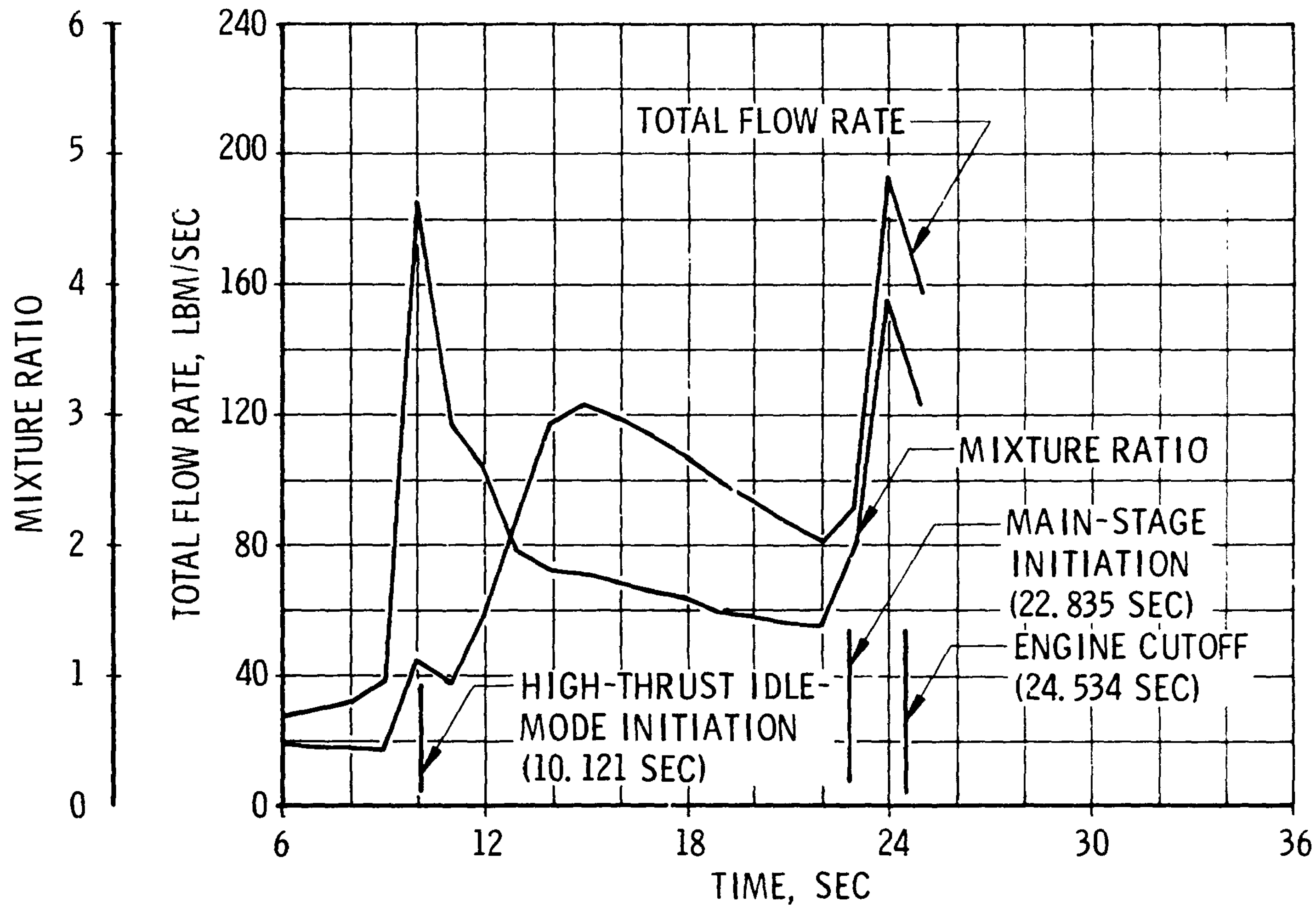
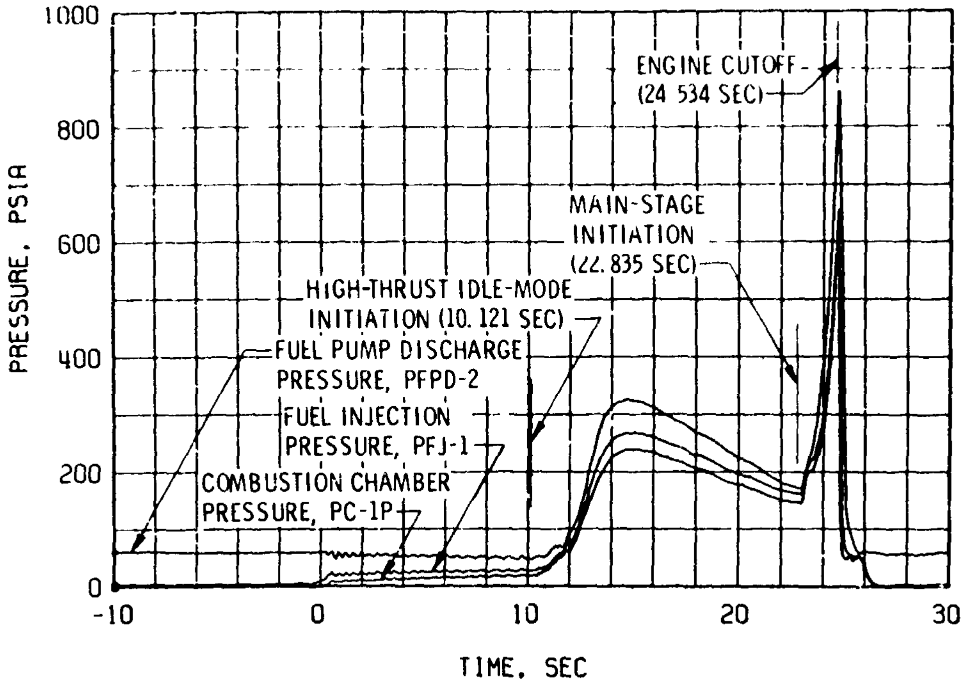
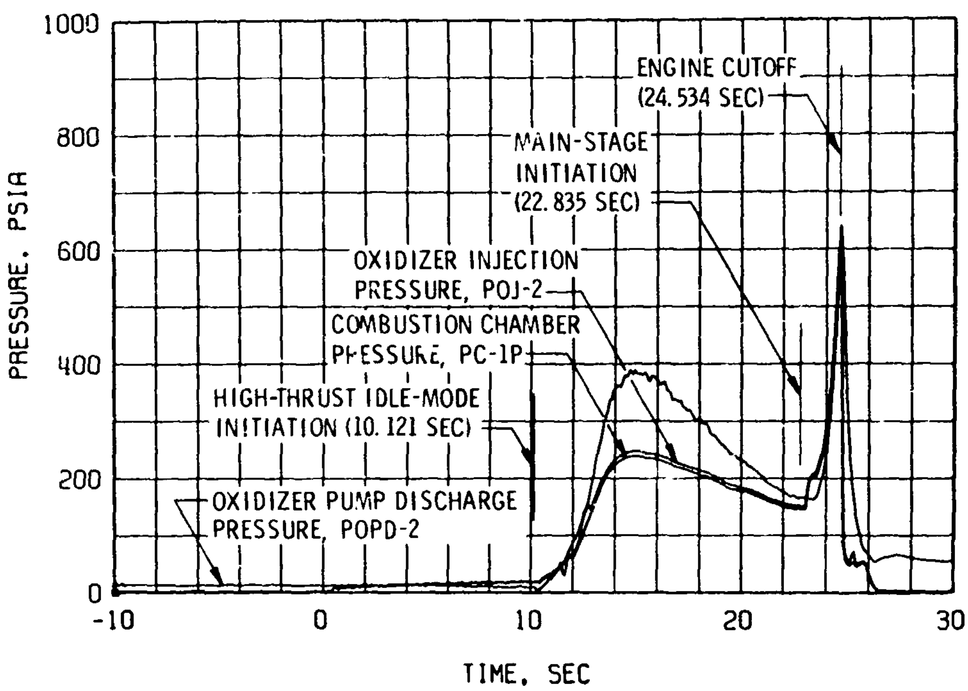


Fig. 22 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 12A



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge, Oxidizer Injection, and Combustion Chamber Pressure

Fig. 23 Propellant System Performance, Firing 12A

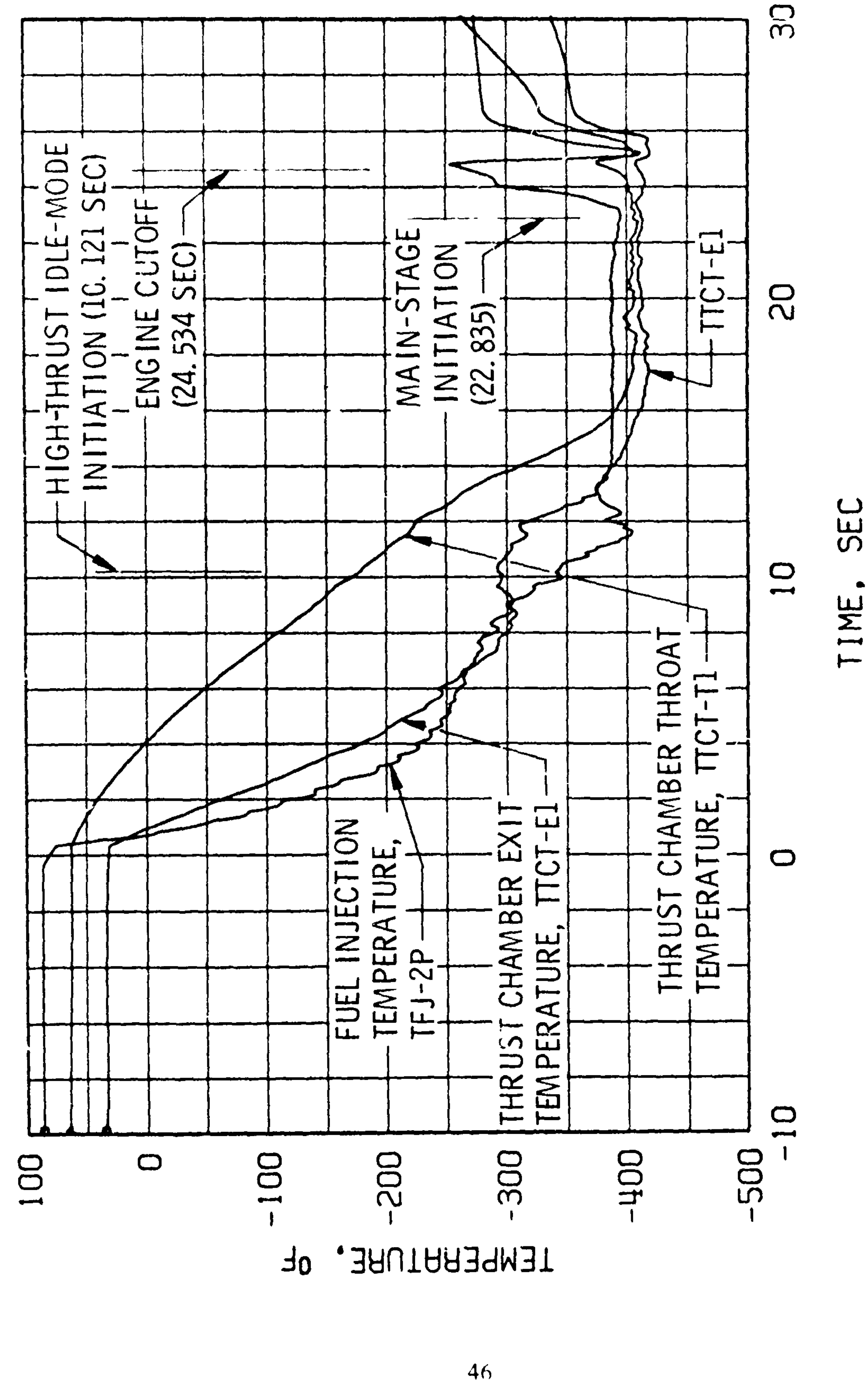


Fig. 24 Thrust Chamber Childown and Fuel Injection Temperature, Firing 12A

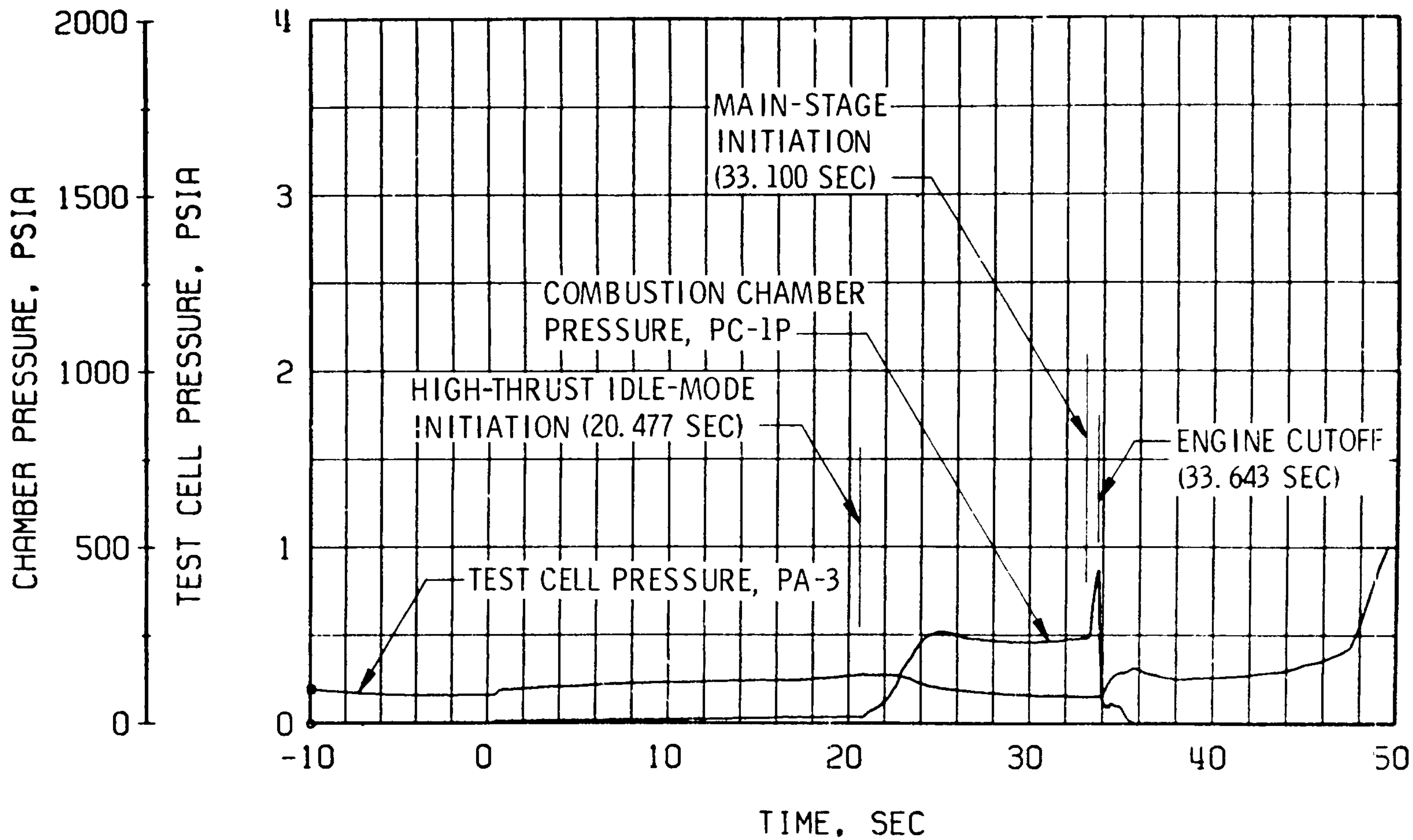


Fig. 25 Engine Ambient and Combustion Chamber Pressure, Firing 12B

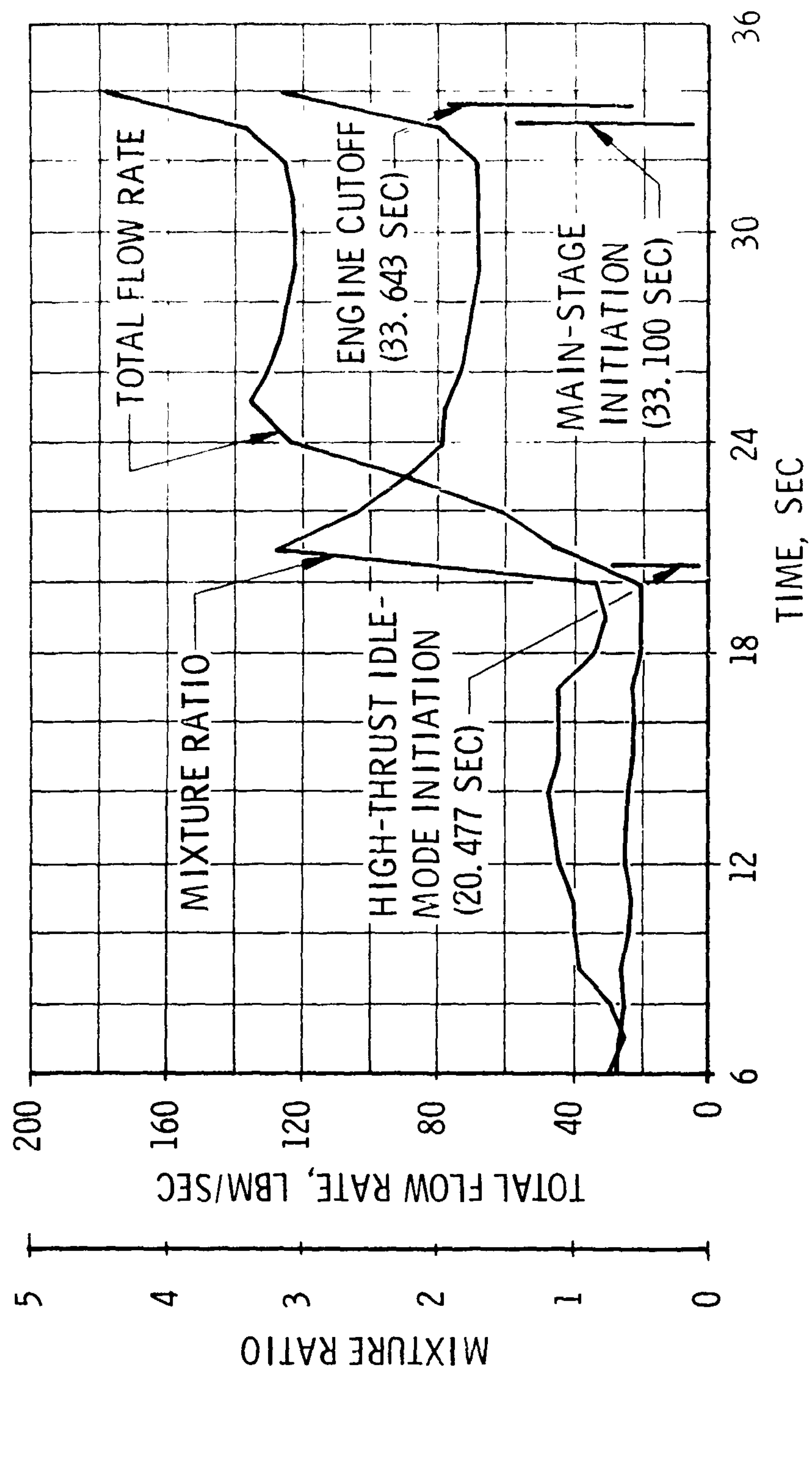
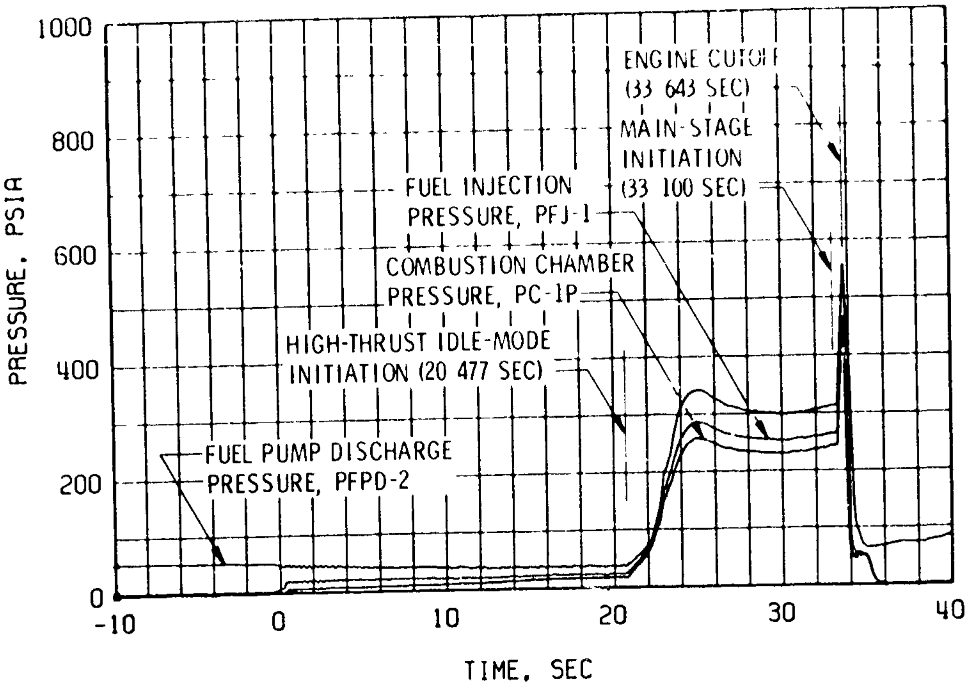
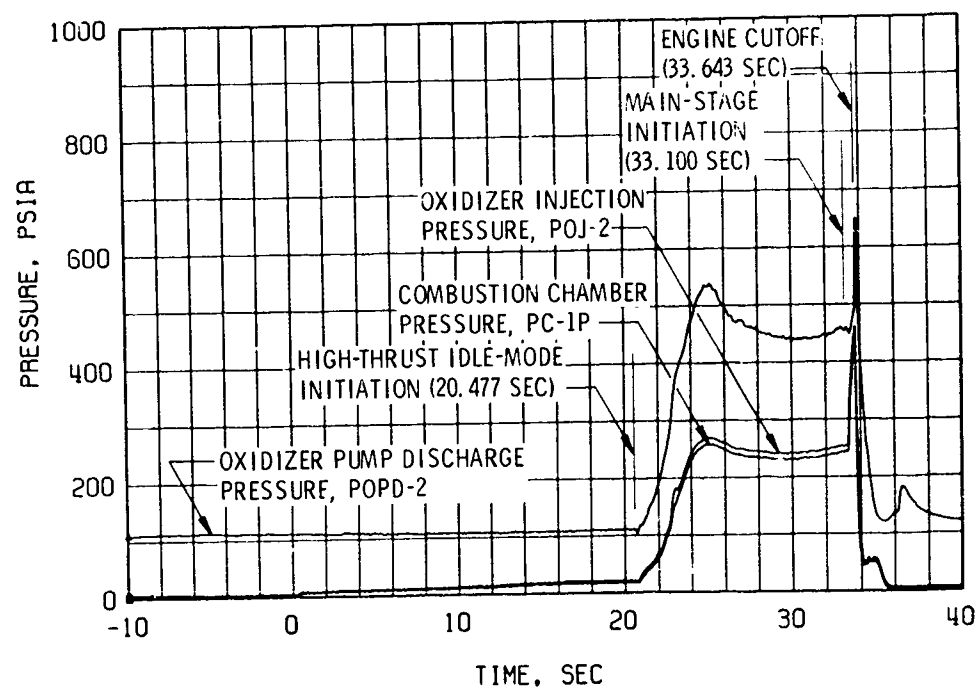


Fig. 26 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 12B



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge, Oxidizer Injector, and Combustion Chamber Pressure

Fig. 27 Propellant System Performance, Firing 12B

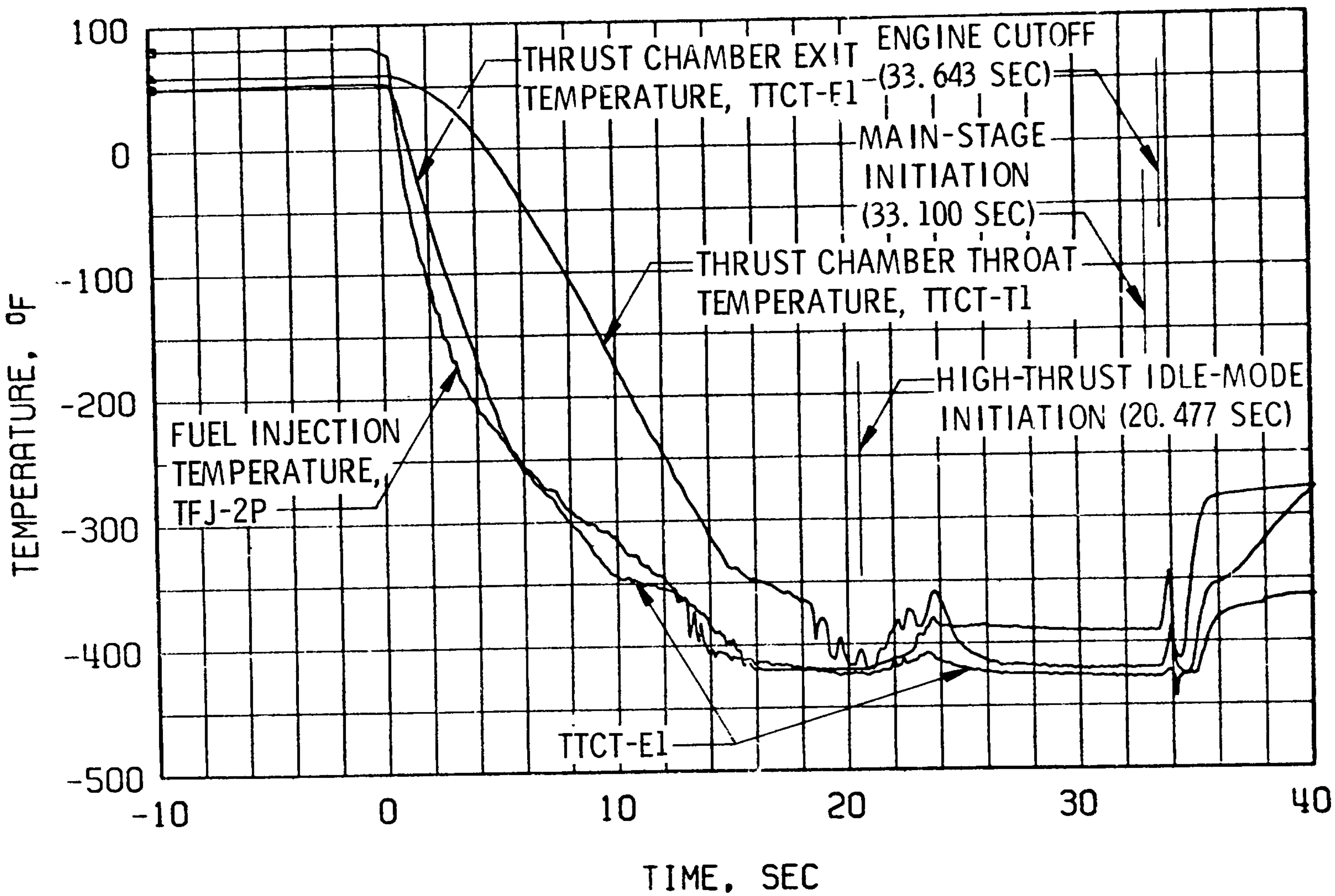


Fig. 28 Thrust Chamber Chilldown and Fuel Injection Temperature, Firing 12B

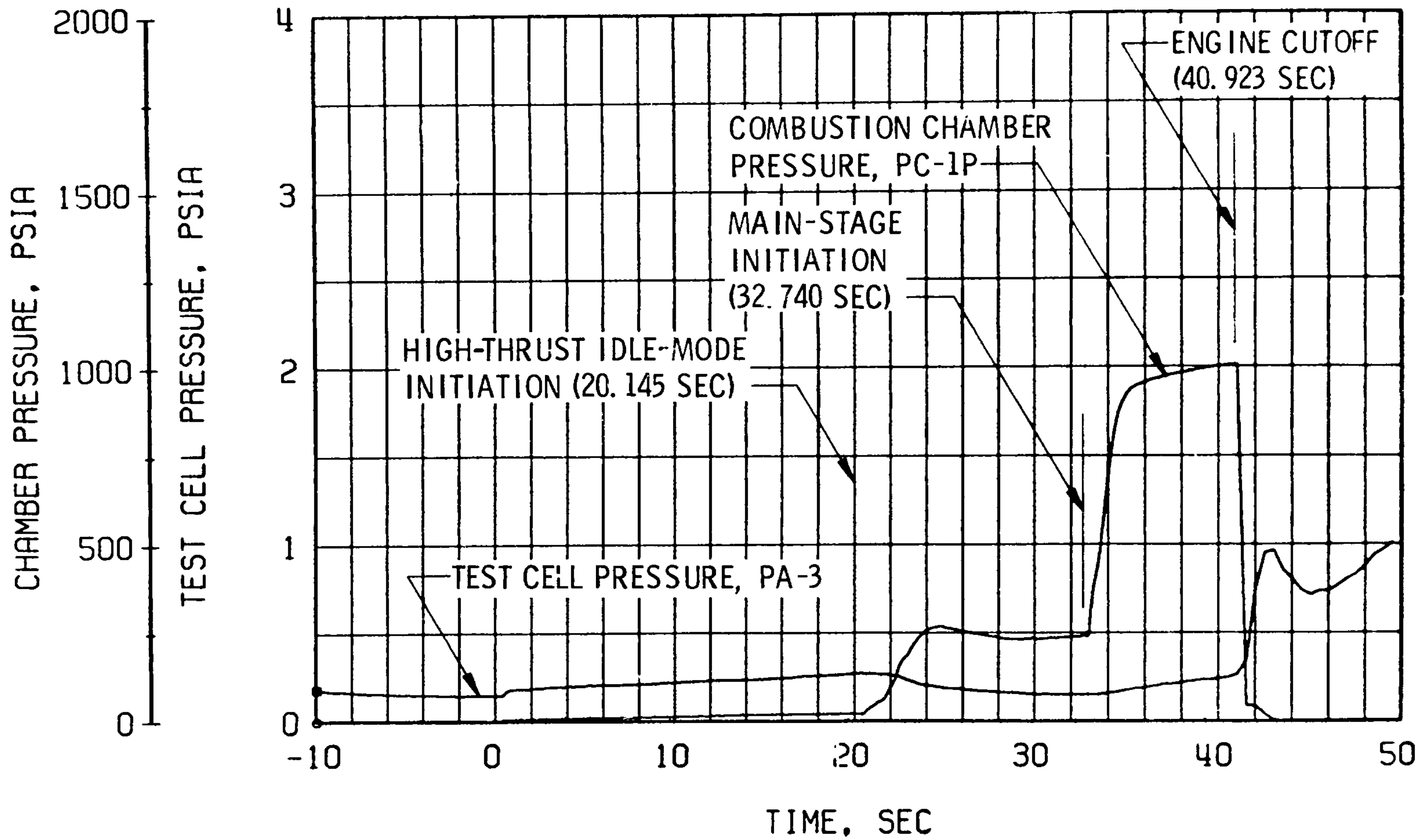


Fig. 29 Engine Ambient and Combustion Chamber Pressure, Firing 12C

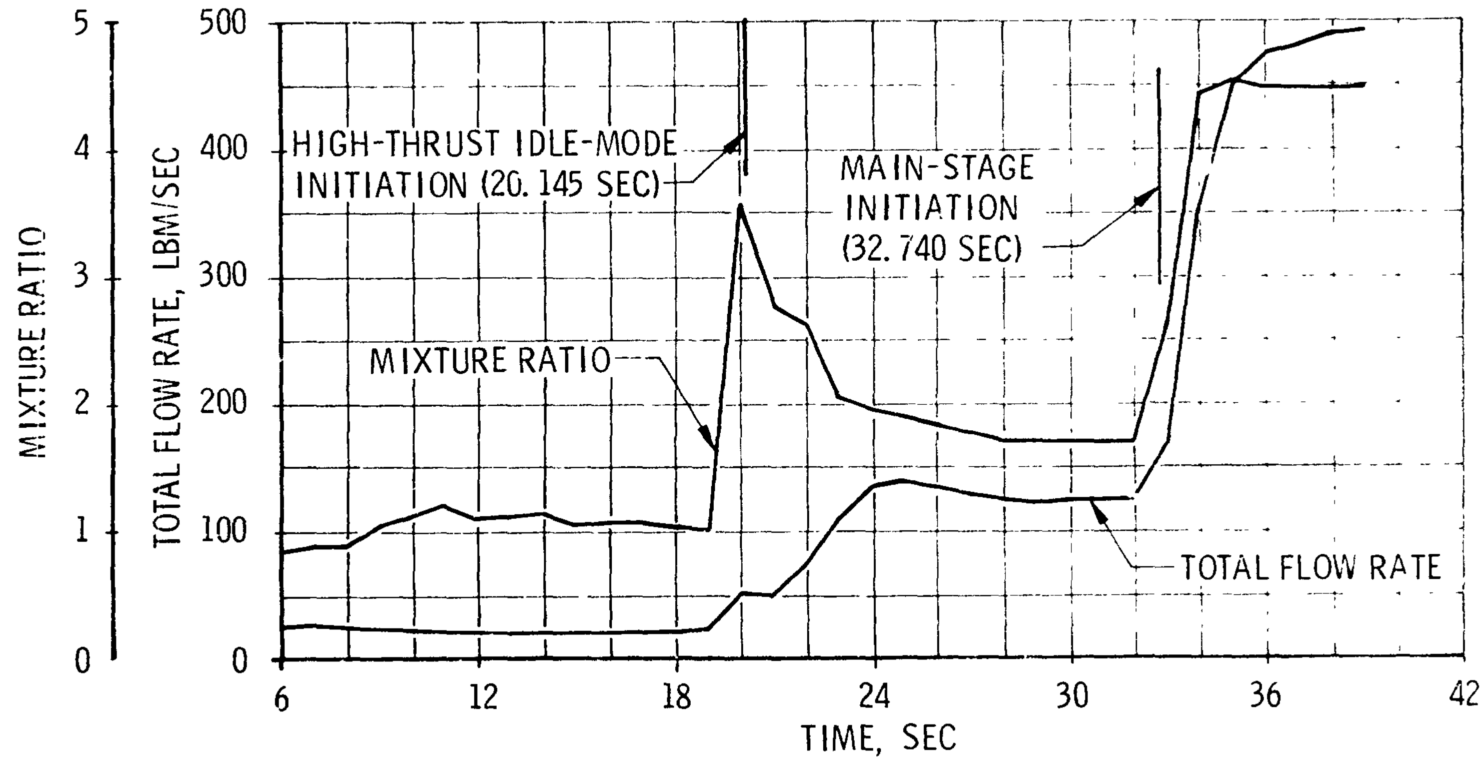
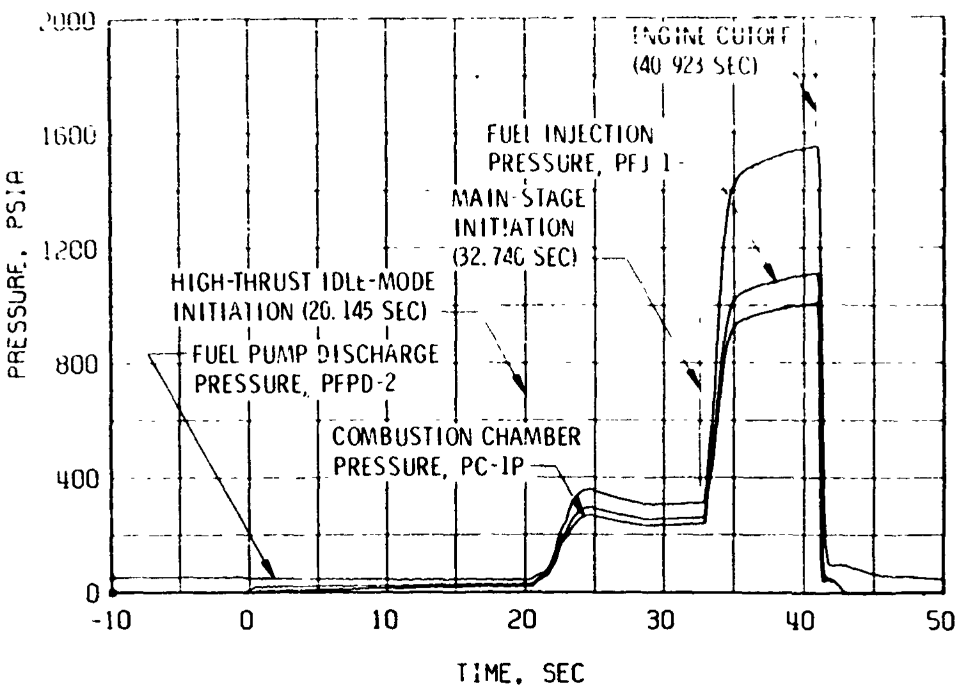
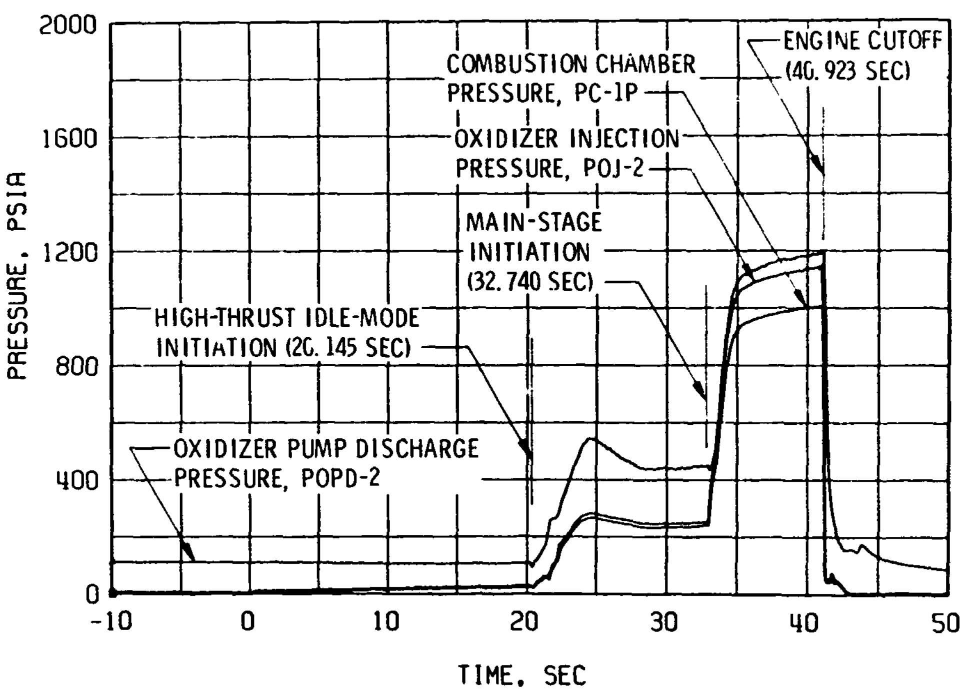


Fig. 30 Engine Total Propellant Flow Rate and Mixture Ratio, Firing 12C



a. Fuel Pump Discharge, Fuel Injection, and Combustion Chamber Pressure



b. Oxidizer Pump Discharge, Oxidizer Injector, and Combustion Chamber Pressure
Fig. 31 Propellant System Performance, Firing 12C

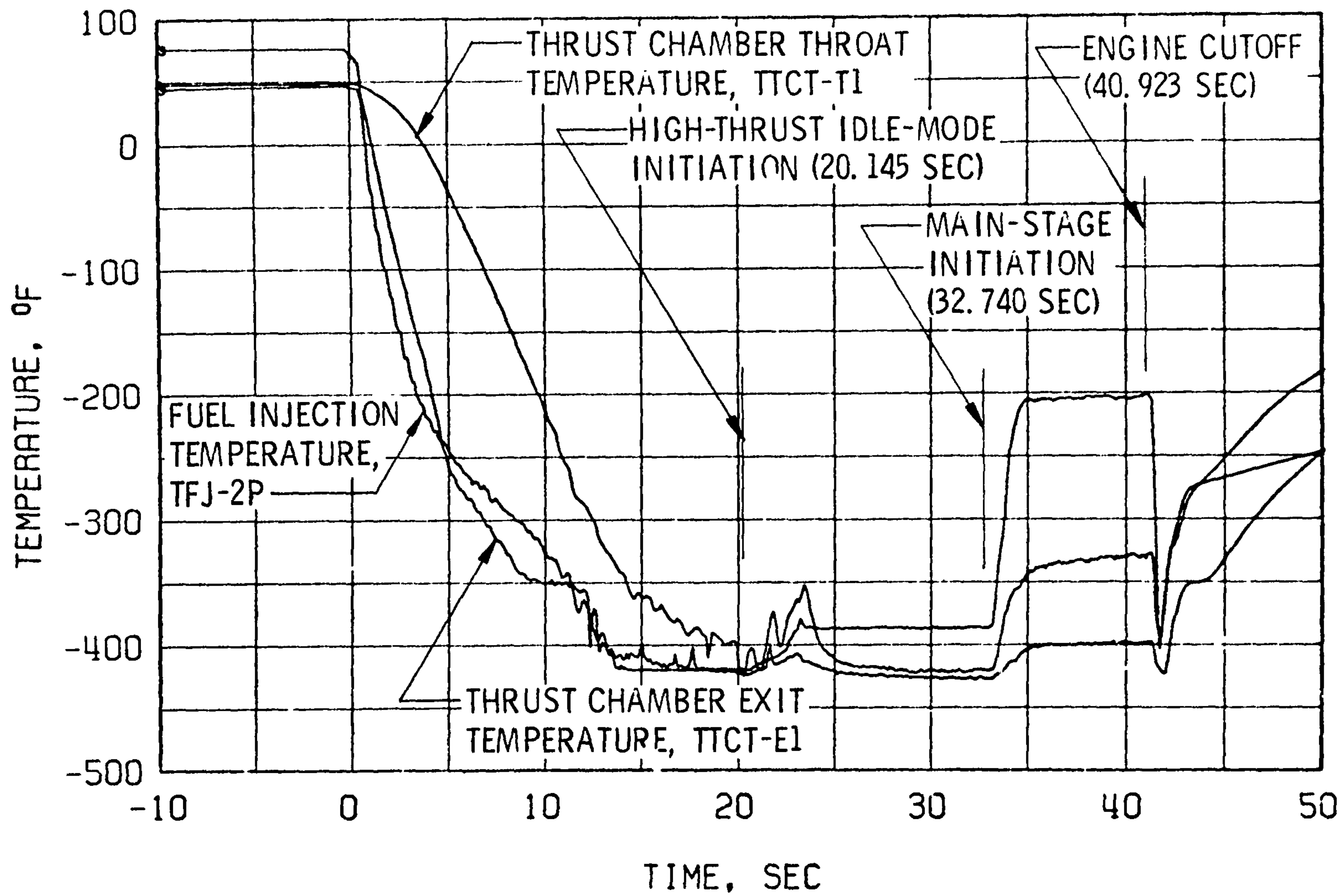


Fig. 32 Thrust Chamber Chilldown and Fuel Injection Temperature, Firing 12C

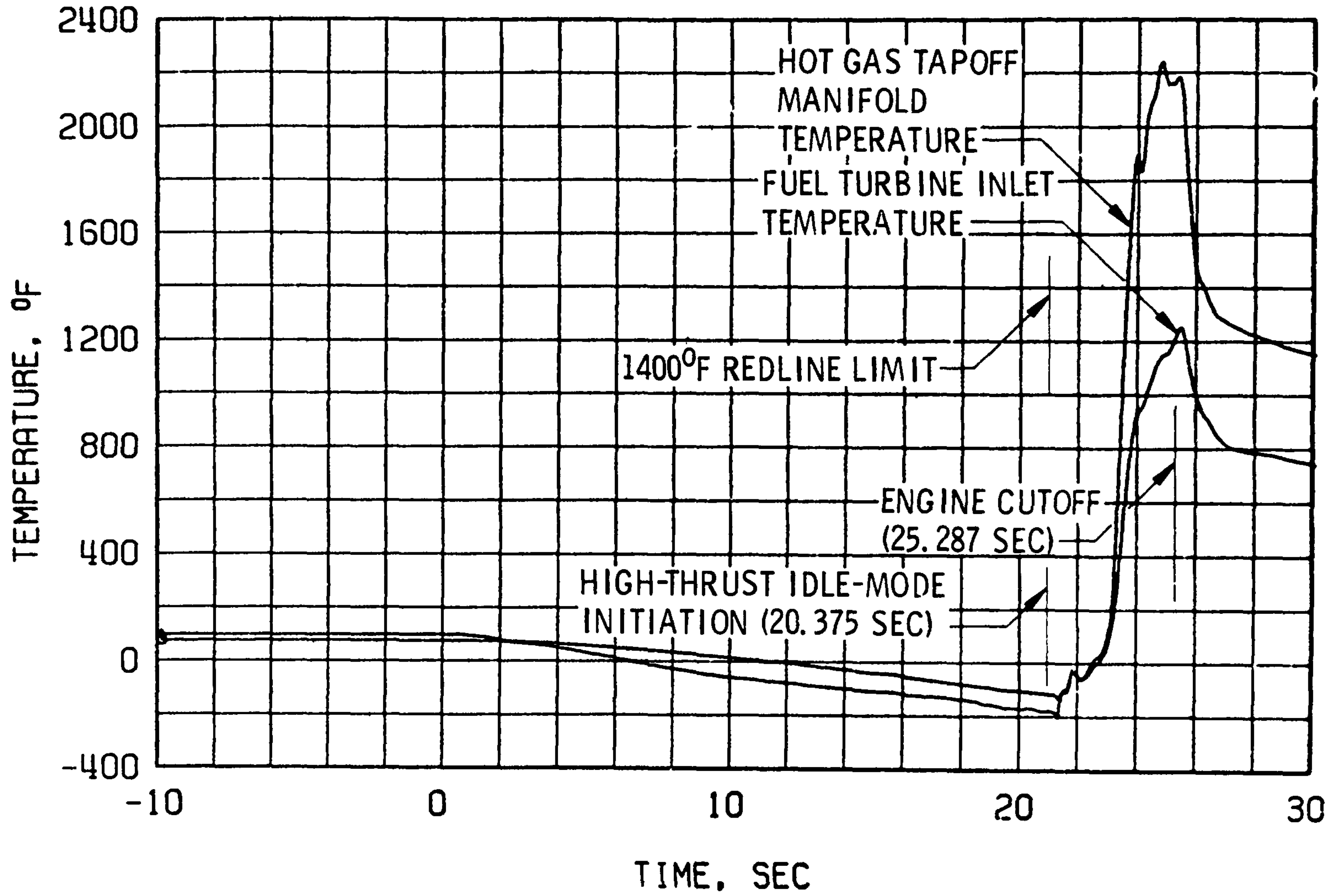
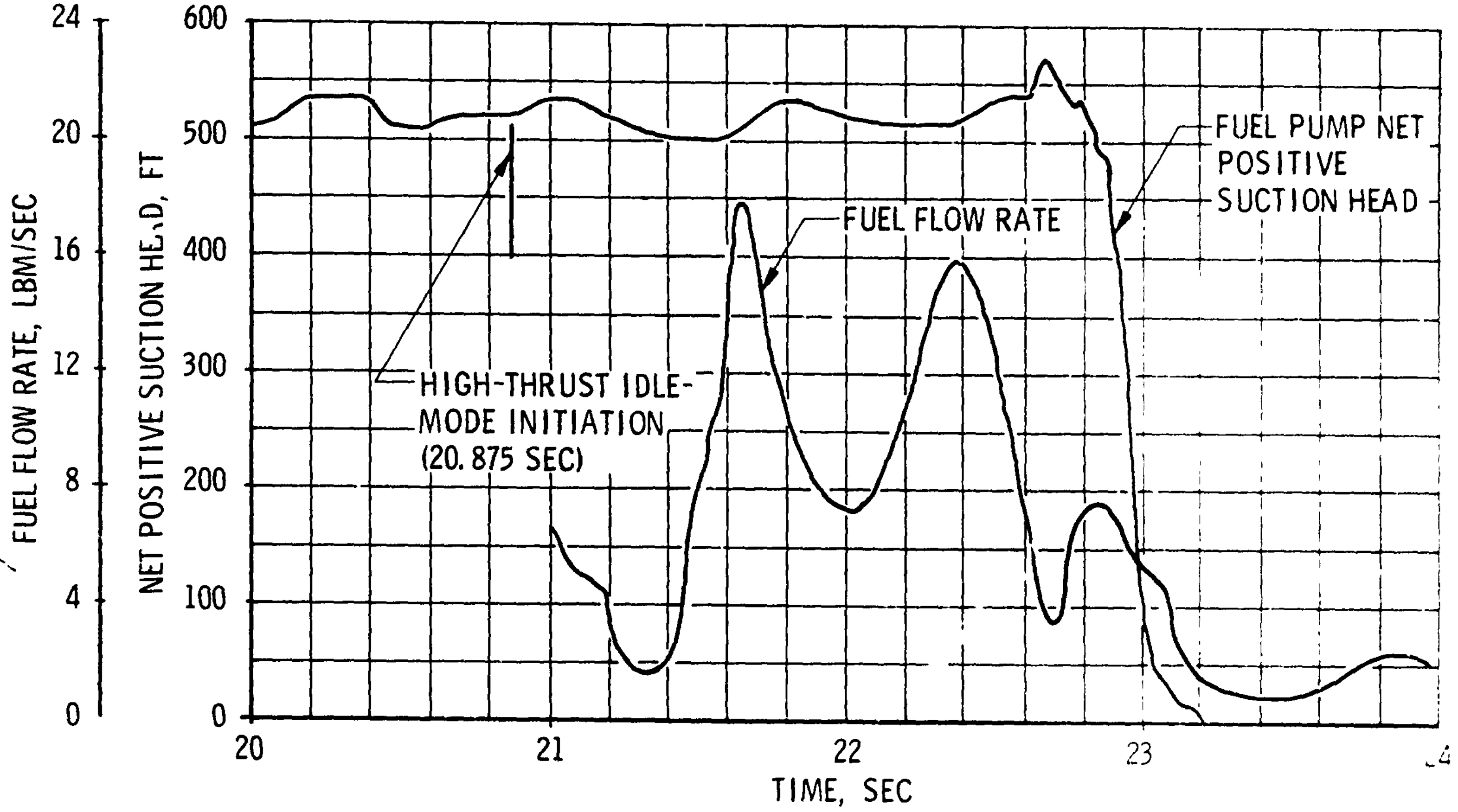
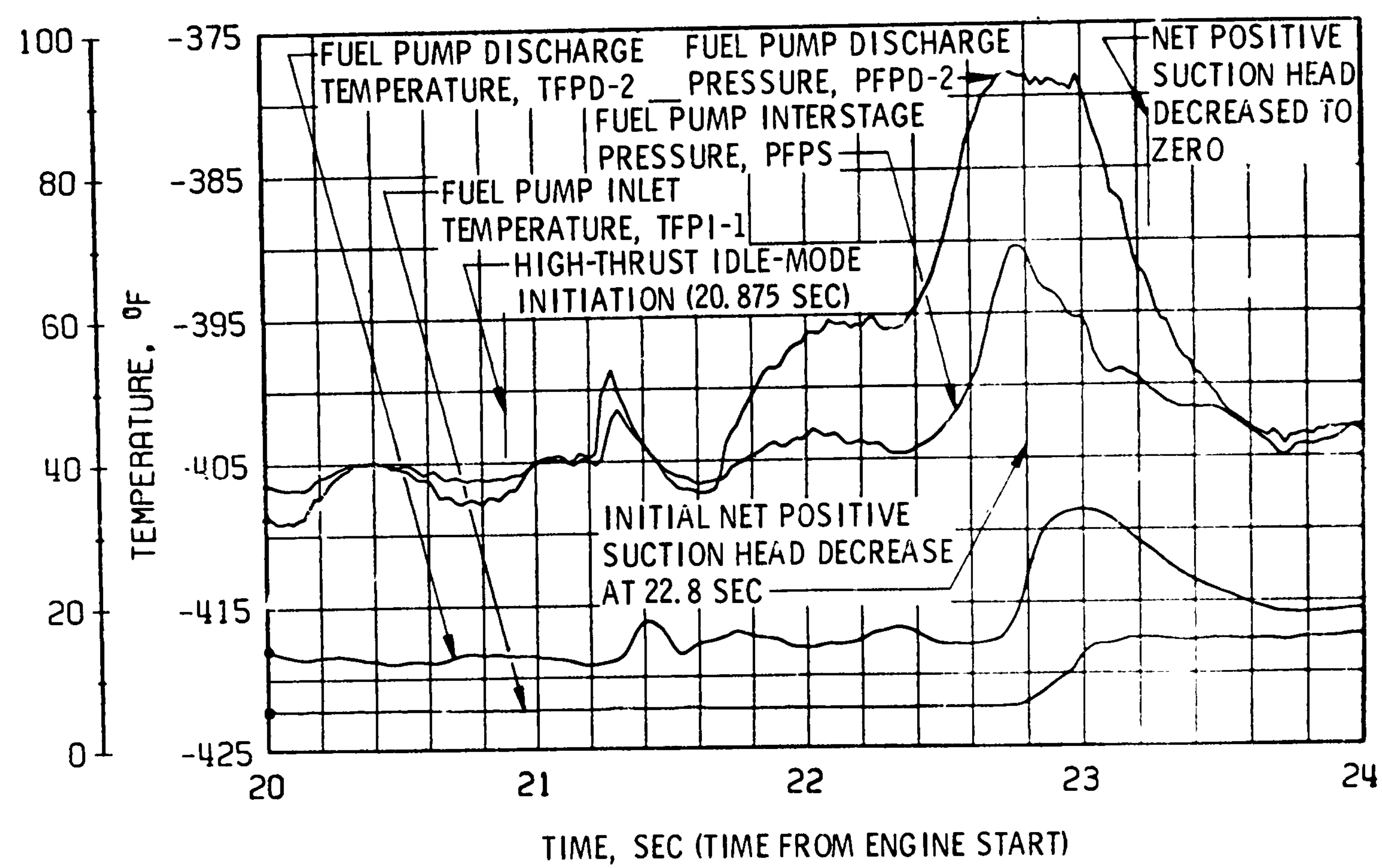


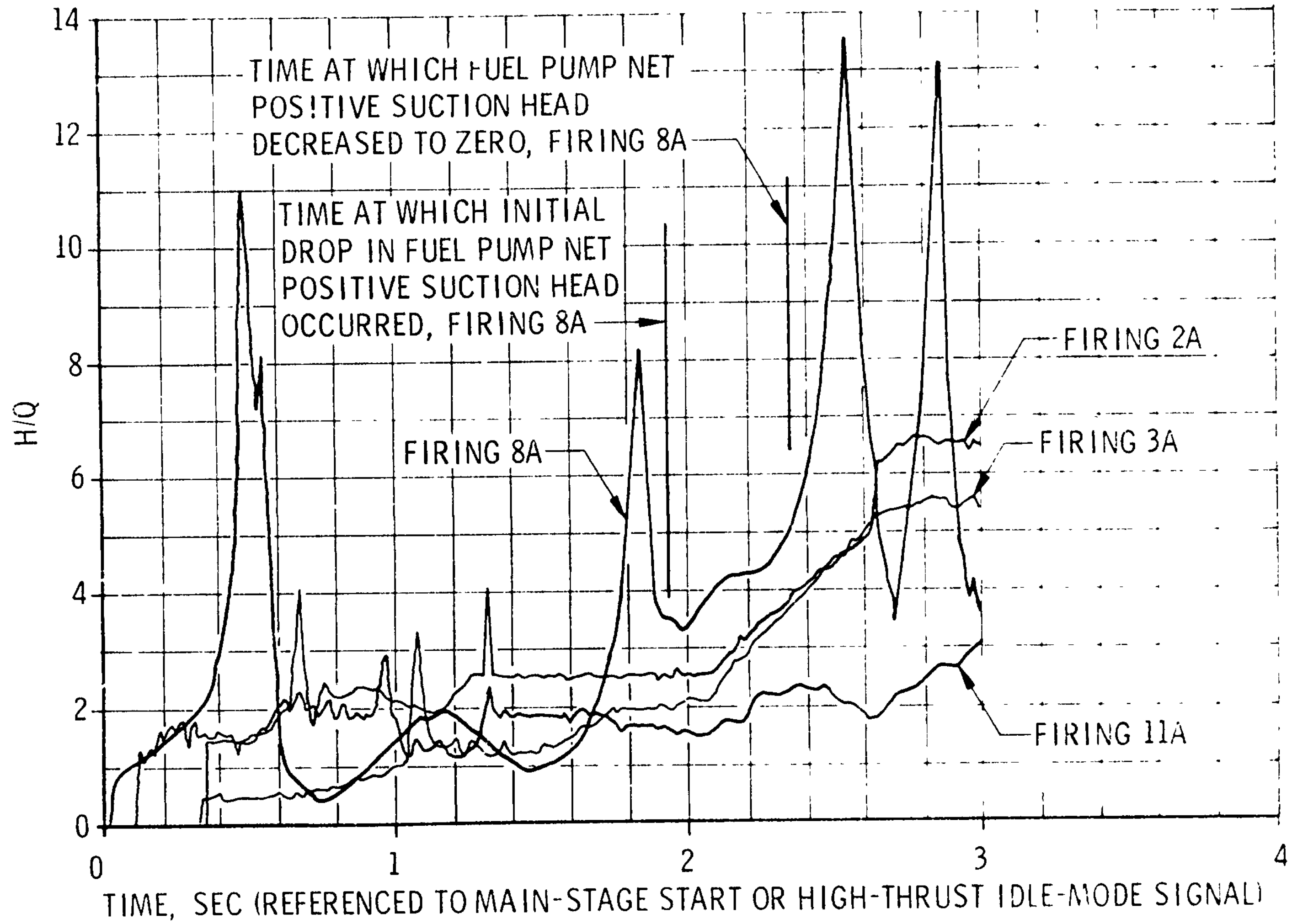
Fig. 33 Hot Gas Tapoff Manifold Temperature, Firing 08A



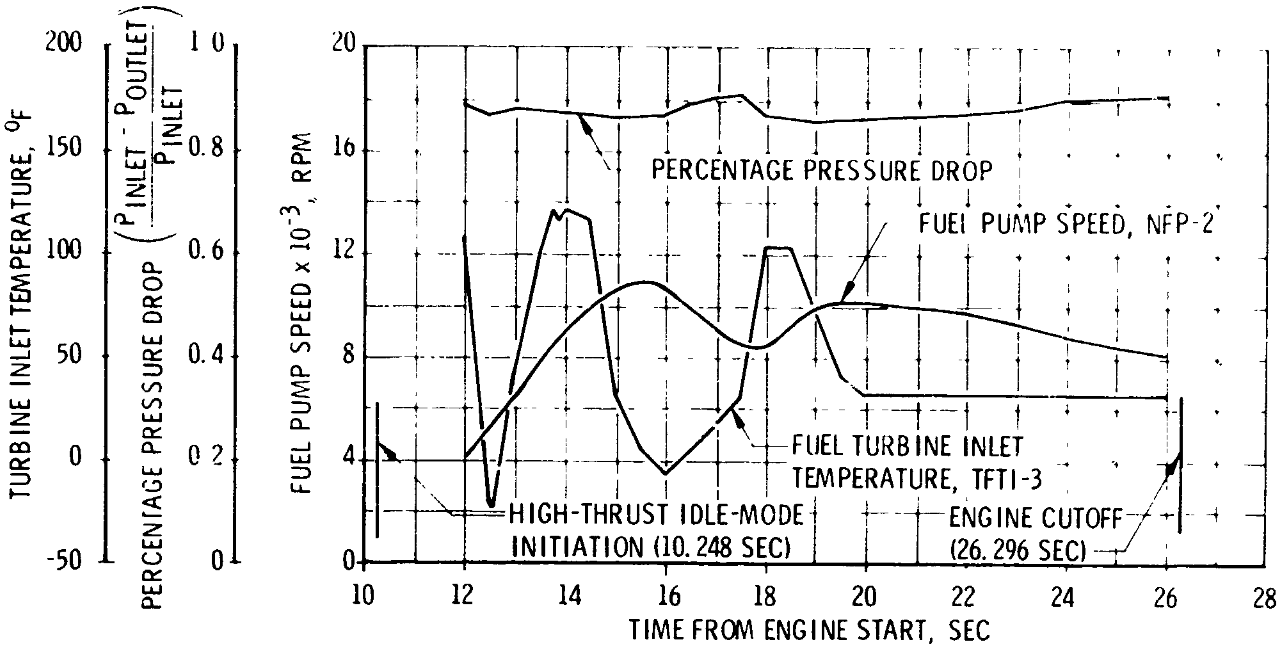
a. Net Positive Suction Head, Firing 8A
Fig. 34 Fuel Pump Operating Characteristics at Speeds below Nominal



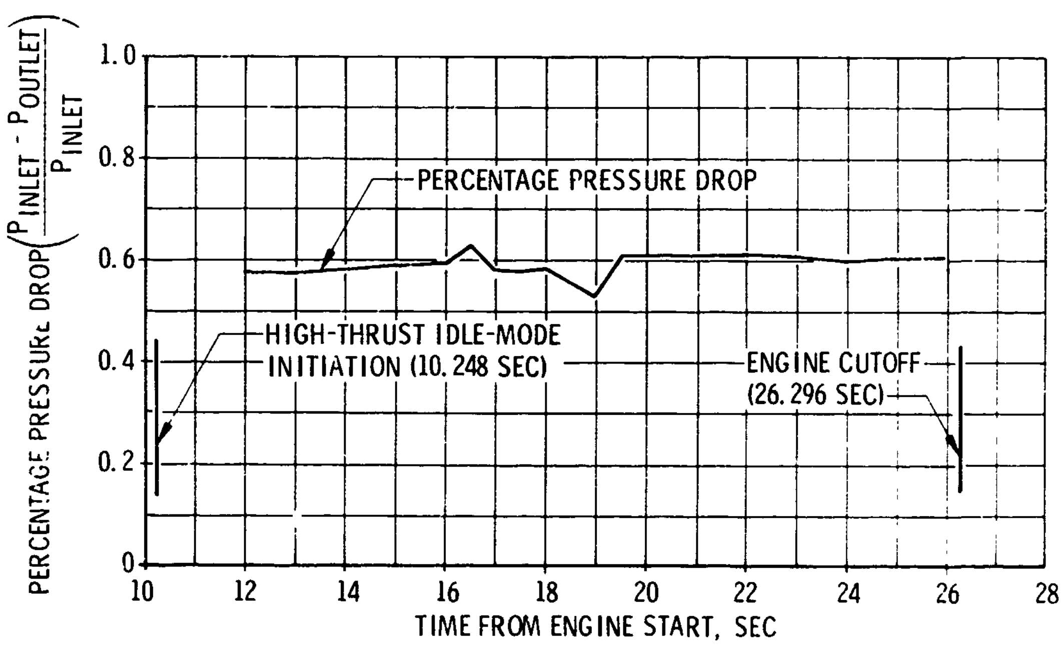
b. Pressure and Temperatures across the Fuel Pump, Firing 8A
Fig. 34 Continued



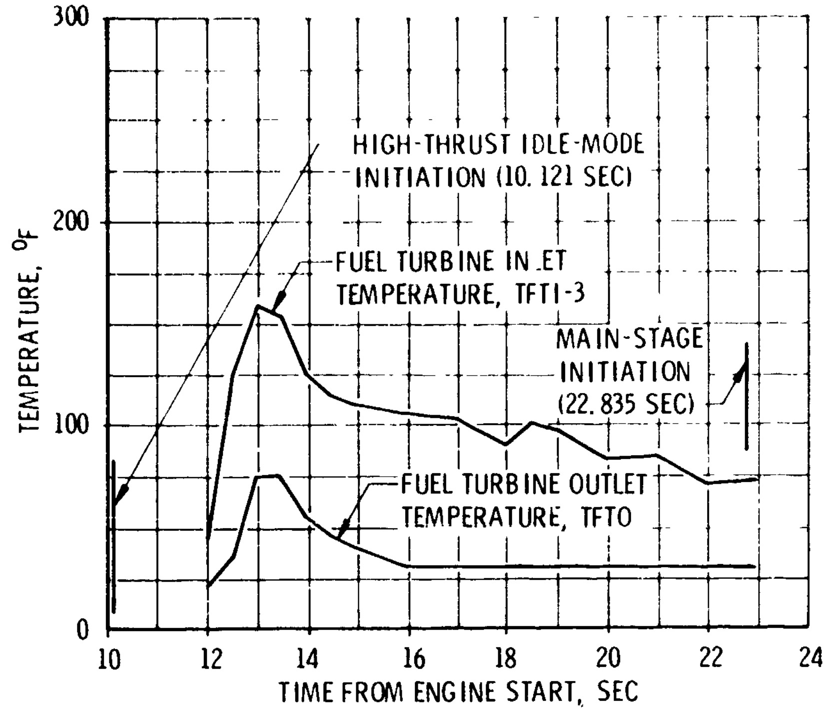
c. Fuel Pump Head/Flow Ratio
Fig. 34 Concluded



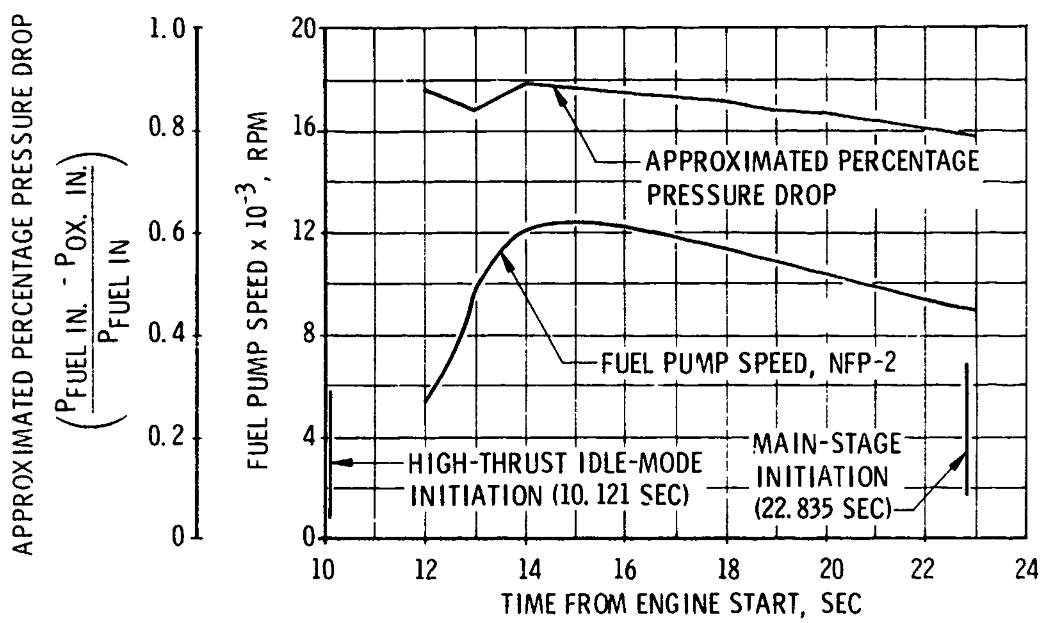
a. Fuel Pump Speed, Turbine Percentage Pressure Drop, and Turbine Inlet Temperature, Firing 11A



b. Oxidizer Turbine Percentage Pressure Drop, Firing 11A
Fig. 35 High-Thrust Idle-Mode Turbine Performance

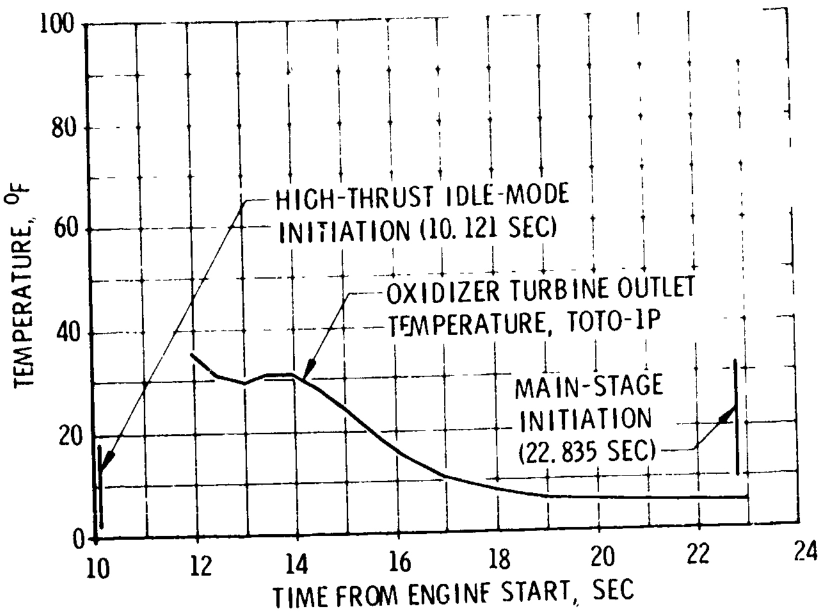


c. **Fuel Turbine Inlet and Outlet Temperatures, Firing 12A**

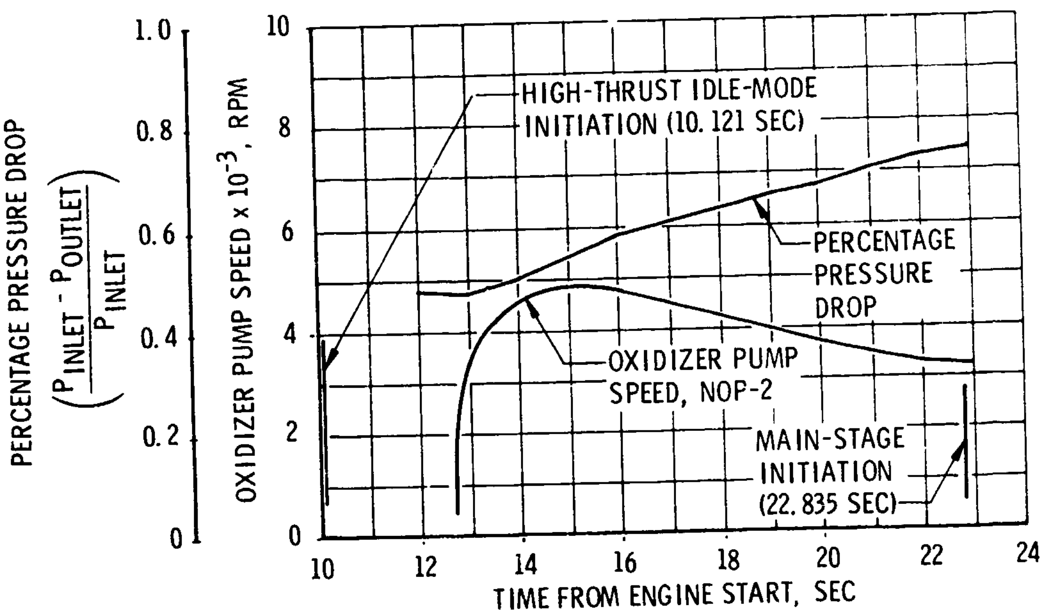


d. **Fuel Pump Speed and Approximated Turbine Percentage Pressure Drop, Firing 12A**

Fig. 35 Continued

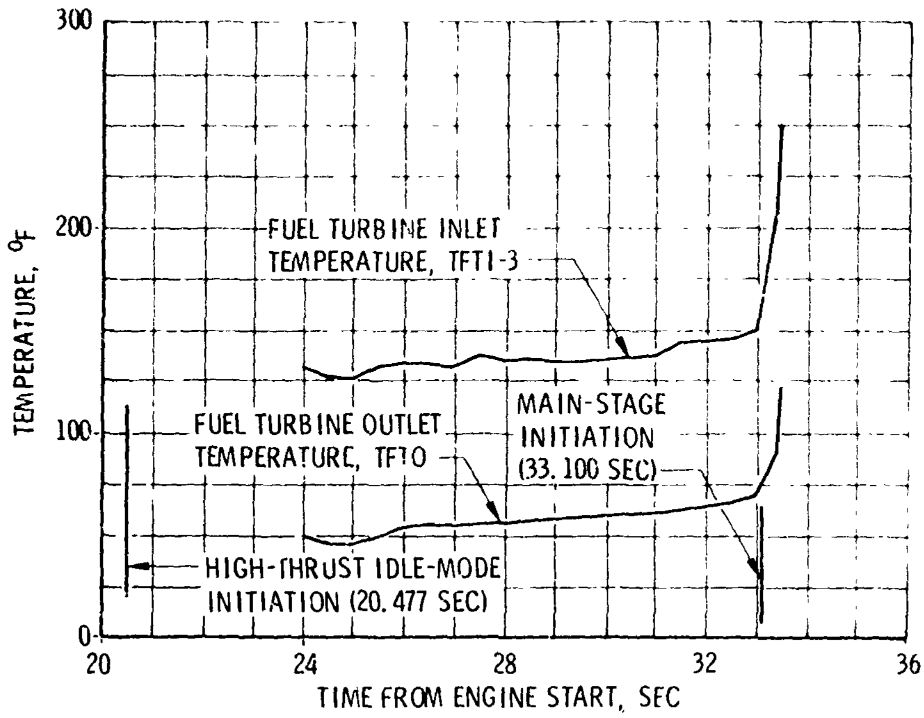


e. Oxidizer Turbine Inlet and Outlet Temperatures, Firing 12A

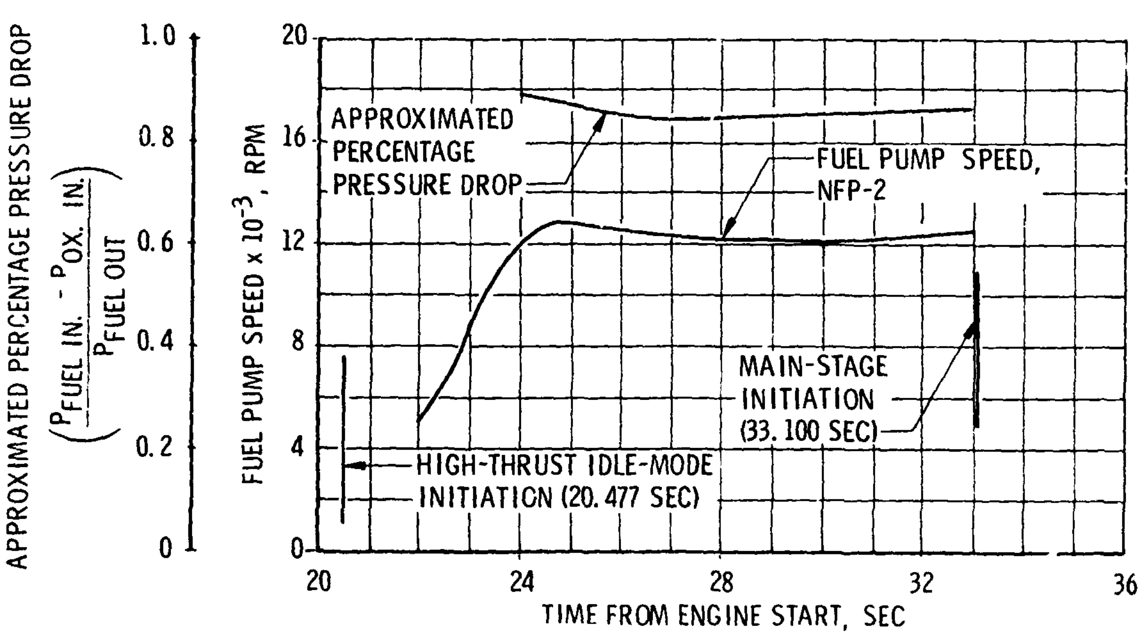


f. Oxidizer Pump Speed and Turbine Percentage Pressure Drop, Firing 12A

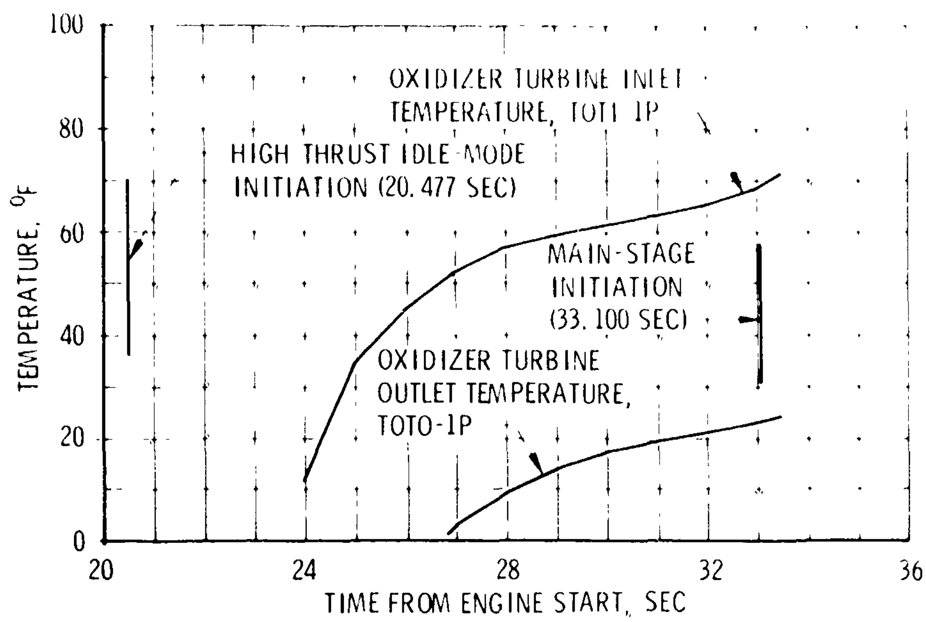
Fig. 35 Continued



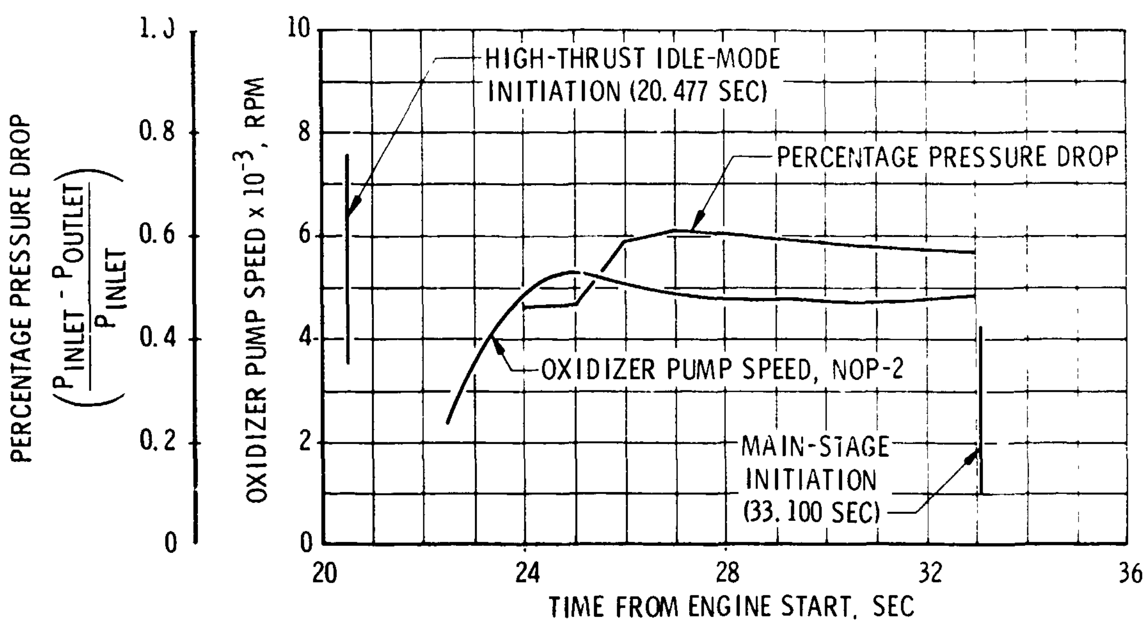
g. Fuel Turbine Inlet and Outlet Temperatures, Firing 12B



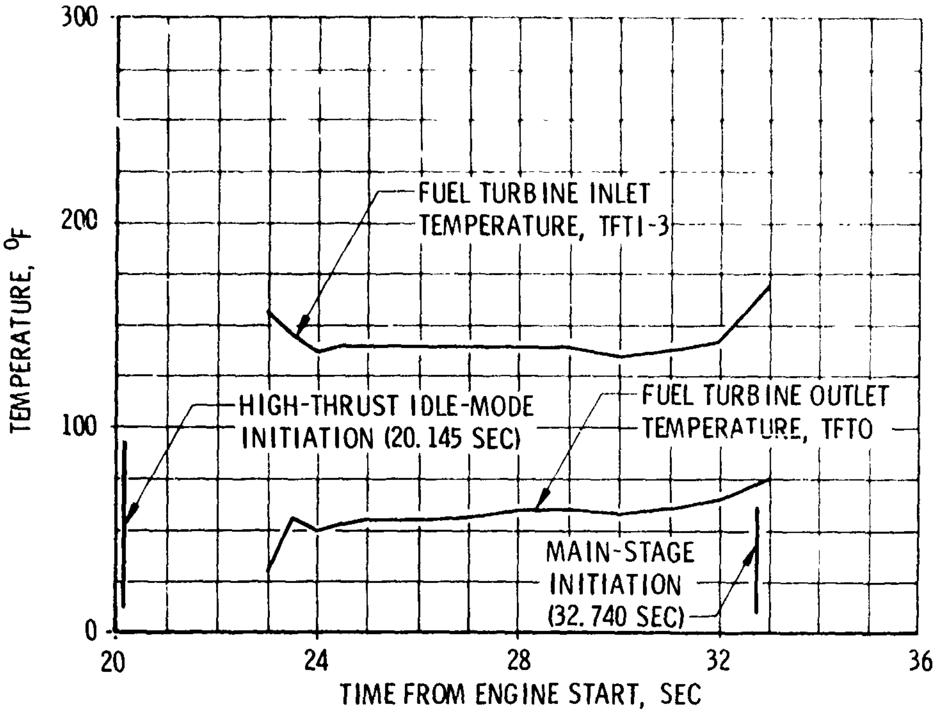
h. Fuel Pump Speed and Approximated Turbine Percentage Pressure Drop, Firing 12B
Fig. 35 Continued



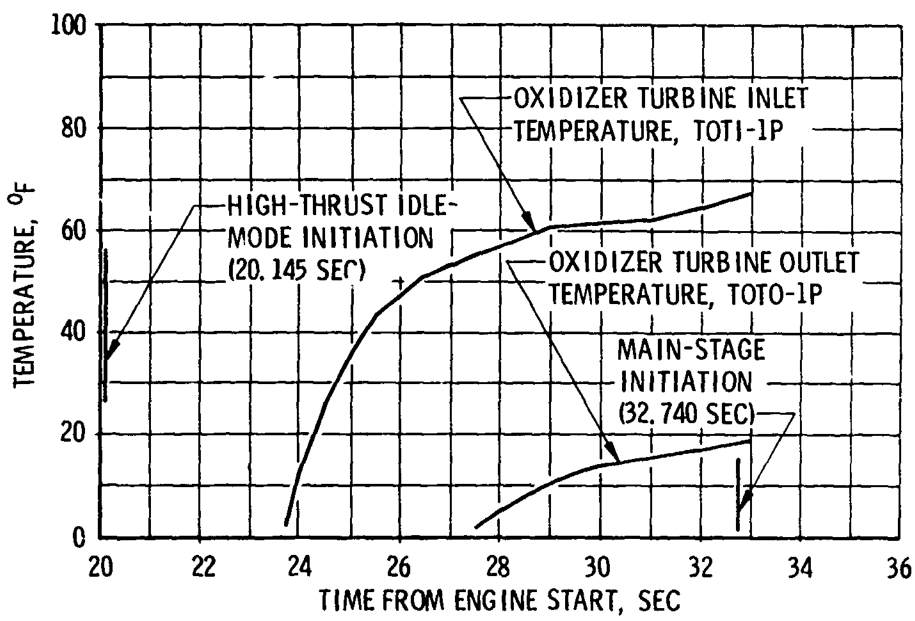
i. Oxidizer Turbine Inlet and Outlet Temperatures, Firing 12B



j. Oxidizer Pump Speed and Turbine Percentage Pressure Drop, Firing 12B
Fig. 35 Continued



k. Fuel Turbine Inlet and Outlet Temperatures, Firing 12C



l. Oxidizer Turbine Inlet and Outlet Temperatures, Firing 12C
Fig. 35 Concluded

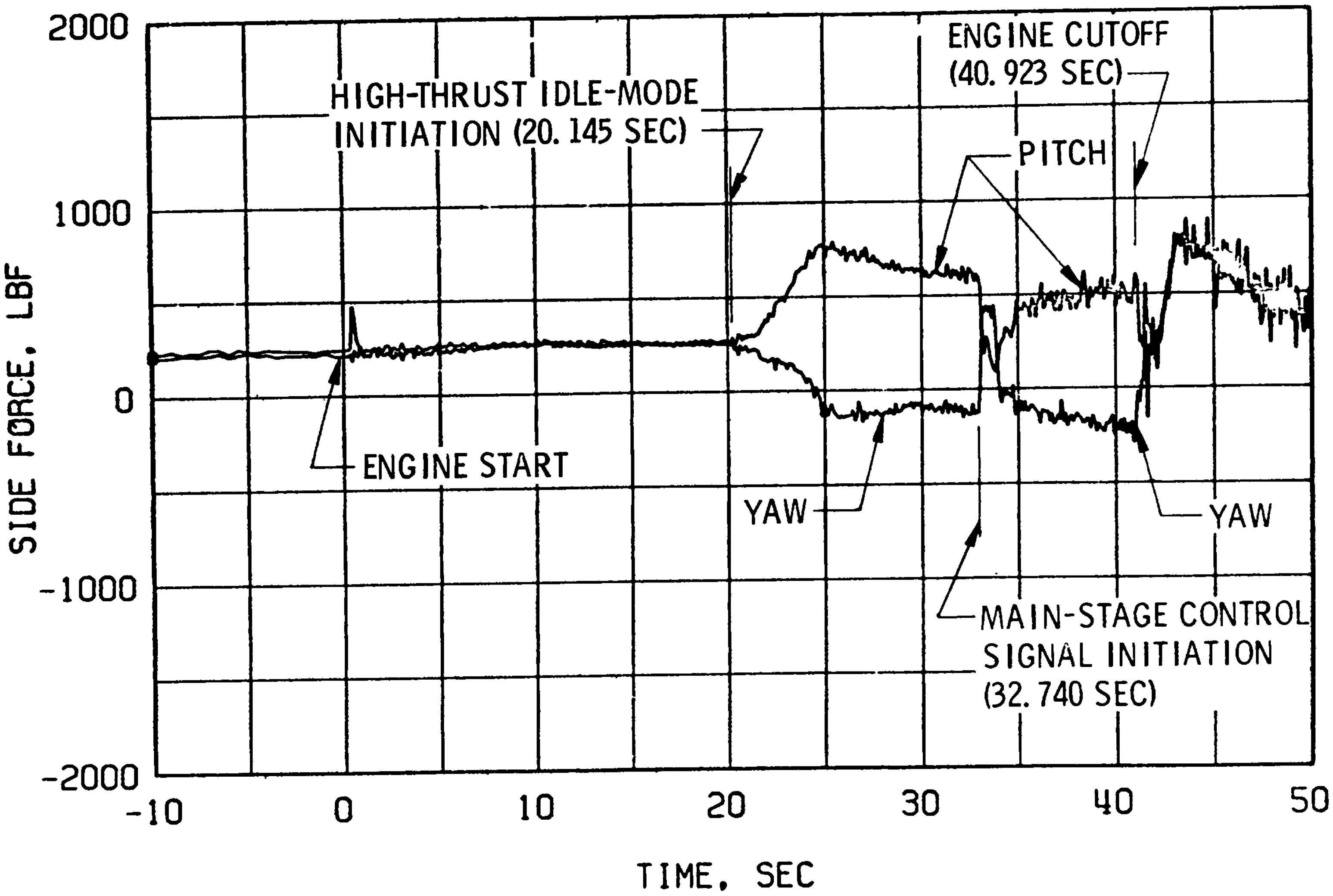


Fig. 36 Pitch and Yaw Side Forces for Engine Operation at Low-Thrust Idle Mode, High-Thrust Idle Mode, and Main Stage

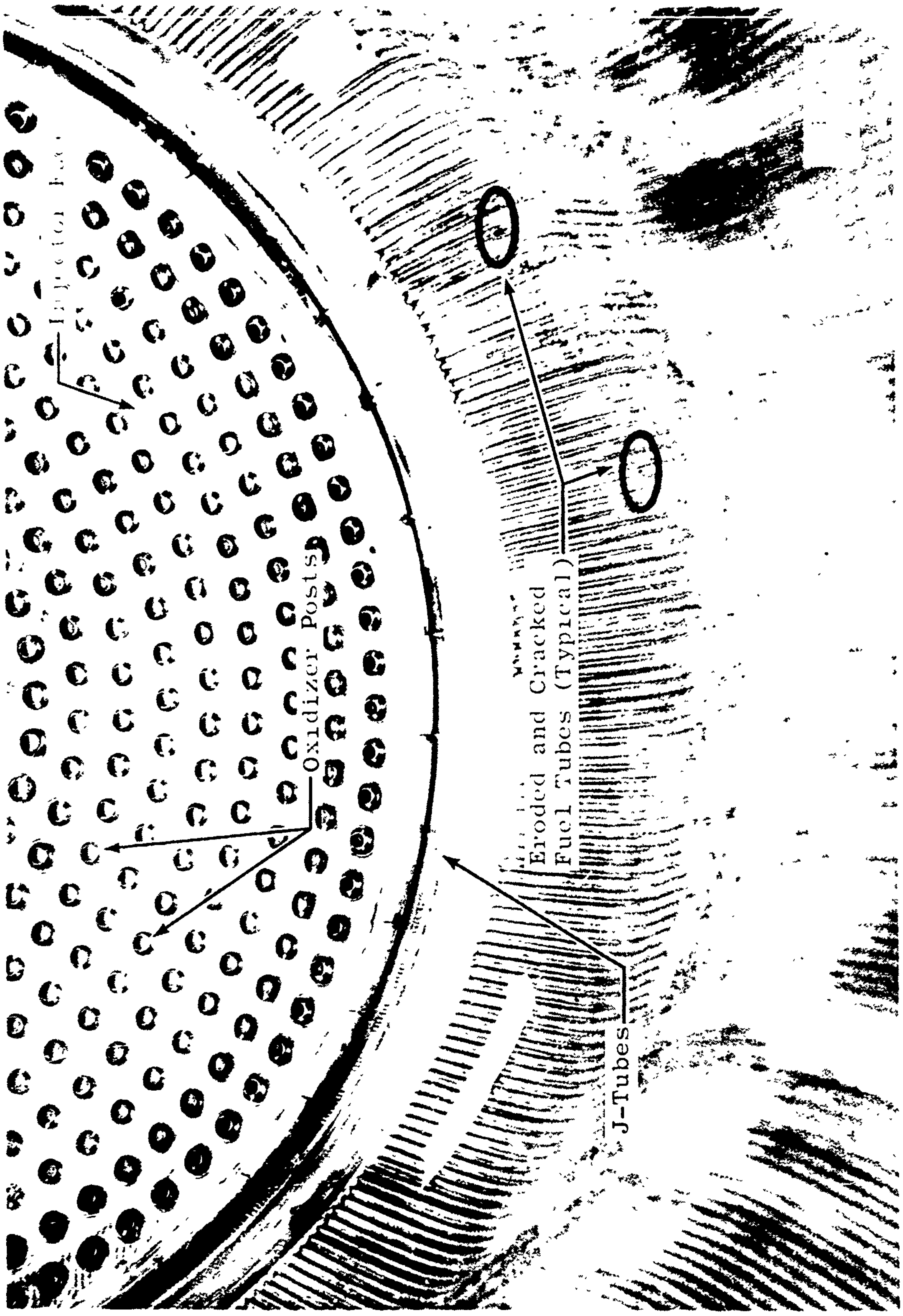


Fig. 37 Thrust Chamber Damage Incurred during Firing 08A

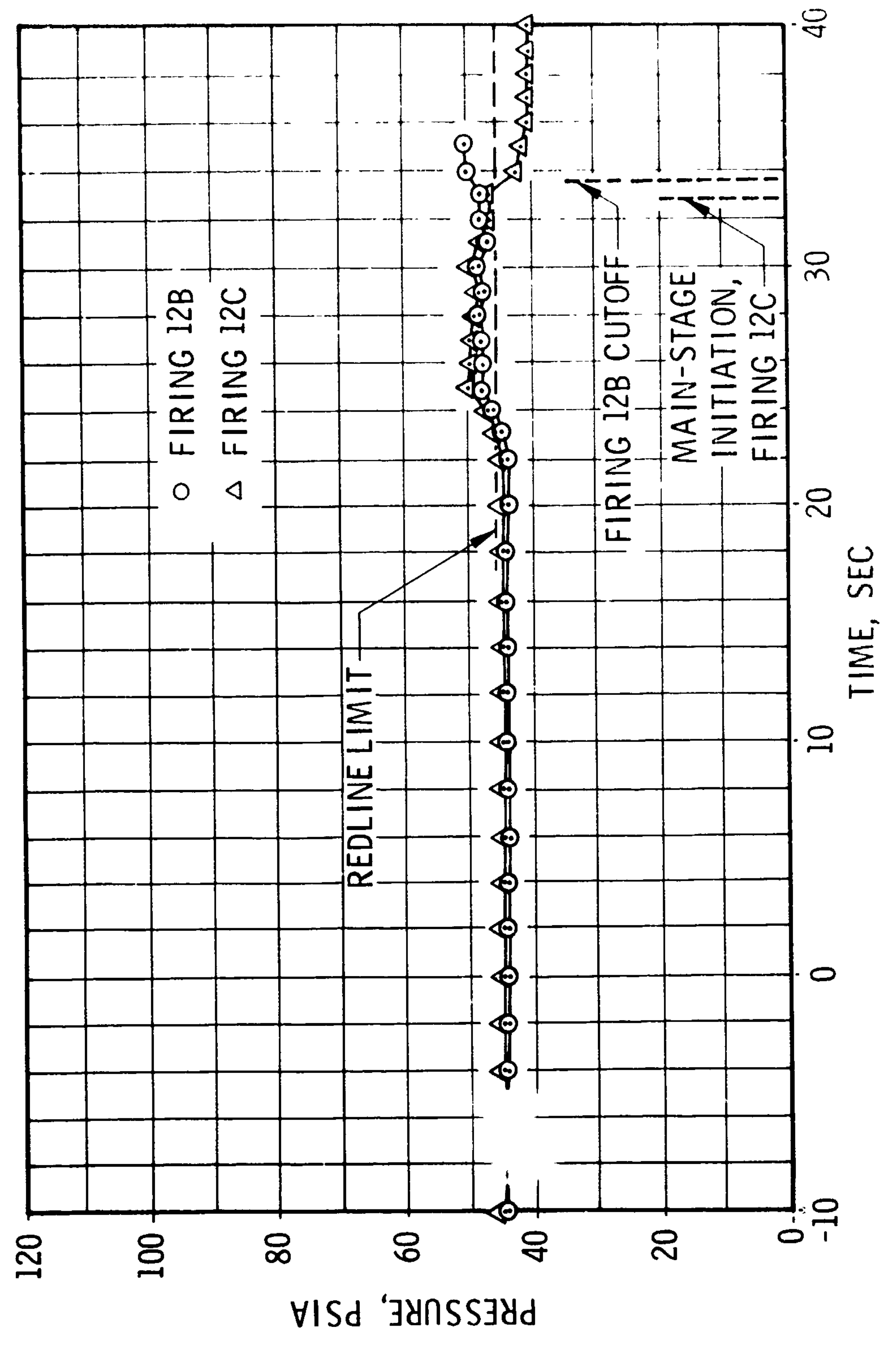


Fig. 38 Oxidizer Pump Inlet Pressure, Firings 12B and 12C

TABLE I
MAJOR ENGINE COMPONENTS
(EFFECTIVE TESTS J4-1902-08, -11, and -12)

Part Name	P/N	S/N
Thrust chamber body assembly	99-210620	4094439
Thrust chamber injector assembly	99-210610-71	4087381
Augmented spark igniter assembly	EWR113811-21	4901310
Ignition detector probe No. 1	3243-2	016
Ignition detector probe No. 2	3423-1	003X
Fuel turbopump assembly	99-461500-31	R004-1A
Oxidizer turbopump assembly	99-460430-21	S003-0A
Main fuel valve	00-411320 X3	8900881
Main oxidizer valve	00-411225 X4	8900929
Idle-mode valve	99-411385	8900867
Thrust chamber bypass valve	99-411180	8900806
	99-411180-X1*	8900954*
Hot gas tapoff valve	99-557824-X2	8900847
Propellant utilization valve	99-251455-X5	8900911
Electrical control package	99-503680	4097867
	99-503670*	4098176*
	99-503670-11**	4097588**
Engine instrumentation package	99-704641	4097437
Pneumatic control package	99-558330	8900817
Restart control assembly	99-503680	4097867
Helium tank assembly	NA5-260212-1	0002
Oxidizer flowmeter	251216	4096874
Fuel flowmeter	251225	4096875
Fuel inlet duct assembly	409900-11	6631788
Oxidizer inlet duct assembly	409899	4052289
Fuel pump discharge duct	99-411082-7	439
Oxidizer pump discharge duct	99-411082-5	439
Thrust chamber bypass duct	99-411079	439
Fuel turbine exhaust bypass duct	307879-11	2143580
Hot gas tapoff duct	99-411808-51	7239768
Solid-propellant turbine starters manifold	99-210921-11	7216433
Heat exchanger and oxidizer turbine exhaust duct	307887	2142922
Crossover duct	307879	2143592

*Denotes installation pretest J4-1902-11
**Denotes installation pretest J4-1902-12

TABLE II
SUMMARY OF ENGINE ORIFICES

Orifice Name	Part No.	Diameter, in.	Test Effective	Comments
Augme. .ed spark igniter fuel supply line	---	---	J4-1902-05	Open
Augmented spark igniter oxidizer supply line	99-652050	0.0999	J4-1902-05	---
Film coolant flow	---	0.581	J4-1902-08	EWR121099
Thrust chamber bypass line	--- ---	1.751 1.749	J4-1902-08 J4-1902-11	EWR121871 EWR121683
Oxidizer turbine bypass nozzle	99-210924	1.996	J4-1902-05	---
Film coolant venturi	---	1.027 inlet 0.744 throat	J4-1902-05	$C_D = 0.97$
Oxidizer idle-mode line	99-411092	0.900	J4-1902-11	EWR121684

TABLE III
ENGINE MODIFICATIONS
(PRETEST J4-1902-08, -11, AND -12)[1]

Modification Number	Completion Date	Description of Modification
Test J4-1902-07 3/20/69		
EWR121099	3/25/69	Installation of new film coolant orifice (0.581-in.-diam)
EWR121871	3/25/69	Installation of new fuel bypass line orifice (1.751-in.-diam)
EWR121881	3/28/69	Installation of 1.584-in. tapoff valve stop (38 deg)
Test J4-1902-08 4/2/68		
EWR121899	4/13/69 (Pretest 09)	Installation of 1.417-in. tapoff valve stop (53 deg)
EWR121683	5/2/69 (Posttest 10)	Installation of new fuel bypass line orifice (1.749-in.-diam)
EWR121684	5/2/69	Installation of oxidizer idle-mode orifice
EWR121685	5/4/69	Main oxidizer valve first-stage open position changed to 10 deg
Test J4-1902-11 5/6/69		
EWR121689	5/7/69	Main oxidizer valve first-stage open position changed to 11 deg
Test J4-1902-12 5/9/69		

[1]Includes all modifications between tests -07 and -12.

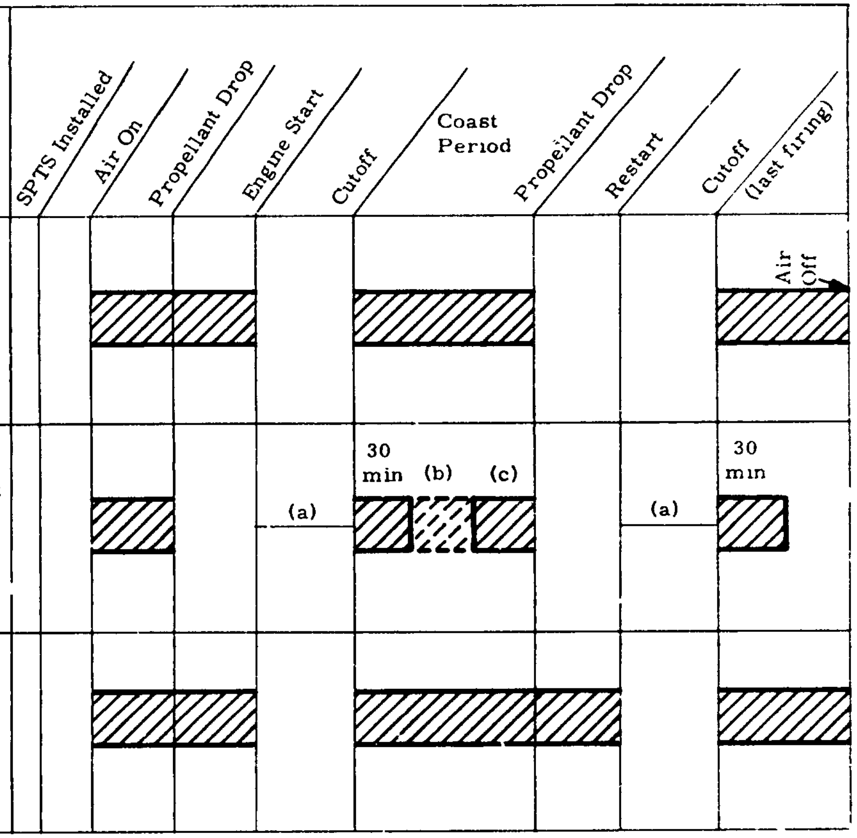
TABLE IV
ENGINE COMPONENT REPLACEMENTS
(PRETEST J4-1902-08, -11, AND -12)[1]

Replacement	Completion Date	Component Replaced
	Test J4-1902-07 3/20/69	
Fuel bypass duct P/N 99-411079 S/N 439	3/25/69	P/N 99-411079 S/N 417
Ignition detect probe No. 1 P/N 3243-2 S/N 016	3/27/69	P/N 3243-1 S/N 002
	Test J4-1902-08 4/2/69	
Oxidizer dome and injector assembly P/N 99-210610-71 S/N 4087381	5/1/69 (Posttest 10)	XEOR 937400 S/N 4087380
Fuel bypass duct P/N 99-411079 S/N 439 "SET"	5/1/69	XEOR 934887-3 XEOR 934887-5 S/N J-112-1 "SET"
	Test J4-1902-11 5/6/69	
Electrical control assembly P/N 99-503670-11 S/N 4097588	5/8/69	P/N 99-503670 S/N 4098176
	Test J4-1902-12 5/9/69	

[1]Includes all component replacements between tests -07 and -12.

TABLE V
ENGINE PURGE SEQUENCE

Purge	Requirement
Oxidizer dome and idle-mode compartment	Nitrogen, 600 ± 25 psia at 100°F and customer connect panel (150 scfm)
Thrust chamber jacket, film coolant, and turbopump purges	Helium, 150 ± 25 psia at +50 to 150°F at customer connect panel (125 scfm)
Fuel and oxidizer turbopump purges (d)	Nitrogen, 600 ± 25 psia at 100°F and customer connect panel (150 scfm)



(a) Engine-Supplied Oxidizer Turbopump Intermediate Seal Cavity Purge
(b) Anytime Facility Water On
(c) 30 min before Propellant Drop
(d) Employed on Test J4-1902-12

TABLE VI
SUMMARY OF TEST REQUIREMENTS AND RESULTS

Firing number	J4-1902-08A Target	J4-1902-08A Actual	J4-1902-11A Target	J4-1902-11A Actual	J4-1902-11B Target	J4-1902-11B Actual
Firing date/time of day	4/2/69	0943	5/6/69	1356	5/6/69	1455
Pressure altitude at t_0, ft (Ref 1)	100,000	8?,000	100,000	80,500	100,000	92,500
Low-thrust idle-mode duration, sec ①	20 0	20 875	10 0	10 248	20 0	19 998
High-thrust idle-mode duration, sec ①	20 0	4 412	15 0	16 048	15 0	15 030
Main-stage duration, sec ①	---	---	---	---	---	---
Fuel pump inlet pressure at t_0, psia	33 0 ± 1.0	33 2	40 0 ± 1 0	40.1	40 0 ± 1 0	39 9
Fuel pump inlet temperature at t_0, °F	---	-417 7	---	-416 7	---	-405 9
Fuel tank bulk temperature at t_0, °F	-422 4 ± 0 4	-422 4	-422 0 ± 0 4	-422 3	[illegible]	-422 3
Oxidizer pump inlet pressure at t_0, psia	39 0 ± 1 0	39 8	39 0 ± 1 0	38 0	45 0 ± 1 0	44 4
Oxidizer pump inlet temperature at t_0, °F	---	-291 8	---	-291 2	---	-276 6
Oxidizer tank bulk temperature at t_0, °F	-295 0 ± 0 4	-295 2	-295 0 ± 0 4	-295 0	-295 0 ± 0 4	-295 2
Fuel injection temperature at t_0, °F	50 ± 25	92	---	81	---	58
Helium tank conditions at t_0 — Pressure, psia	3450^{+40}_{-200}	3233	3450^{+40}_{-200}	3298	---	[illegible]
Helium tank conditions at t_0 — Temperature, °F	---	106	---	102	---	84
Main fuel valve temperature at t_0, °F	---	77	50 ± 25	82	50 ± 25	90
Augmented spark igniter ignition detected, sec (Ref t_0) ①	---	0 182	---	0 440	---	0 36?
Propellant utilization valve position at t_0	Null	Null	Open	Open	Null	Null

Firing number	J4-1902-12A Target	J4-1902-12A Actual	J4-1902-12B Target	J4-1902-12B Actual	J4-1902-12C Target	J4-1902-12C Actual
Firing date/time of day	5/9/69	2023	5 9 69	22[illegible]	[illegible]	[illegible]
Pressure altitude at t_0, ft (Ref 1)	100,000	90,500	100 000	[illegible]	[illegible]	[illegible]
Low-thrust idle-mode duration, sec ①	10 0	10 12[illegible]	20 0	[illegible]	[illegible]	[illegible]
High-thrust idle-mode duration, sec ①	15 0	12 714	[illegible]	12 82	[illegible]	[illegible]
Main-stage duration, sec ①	---	1 699	[illegible]	[illegible]	[illegible]	[illegible]
Fuel pump inlet pressure at t_0, psia	40 0 ± 1 0	40 0		40 0	[illegible]	[illegible]
Fuel pump inlet temperature at t_0, °F	---	-416 1	---	[illegible]	---	[illegible]
Fuel tank bulk temperature at t_0, °F	[illegible]	-422 3	[illegible]	-422 [illegible]	[illegible]	[illegible]
Oxidizer pump inlet pressure at t_0, psia	39 0 ± 1 0	39 6	[illegible]	44 4	[illegible]	[illegible]
Oxidizer pump inlet temperature at t_0, °F	---	-290 8	---	-279 8	---	[illegible]
Oxidizer tank bulk temperature at t_0, °F	[illegible]	-294 8	[illegible]	-29? 2	[illegible]	[illegible]
Fuel injection temperature at t_0, °F	50 ± 25	87	[illegible]	[illegible]	[illegible]	[illegible]
Helium tank conditions at t_0 — Pressure, psia	3450^{+40}_{-200}	3231	---	[illegible]	---	[illegible]
Helium tank conditions at t_0 — Temperature, °F	---	105	---	[illegible]	---	[illegible]
Main fuel valve temperature at t_0, °F	---	80	---	[illegible]	---	[illegible]
Augmented spark igniter ignition detected, sec (Ref t_0) ①	---	0 618	---	[illegible]	---	[illegible]
Propellant utilization valve position at t_0	Open	Open	[illegible]	[illegible]	[illegible]	[illegible]

① Data Reduced from Oscillogram

TABLE VII
ENGINE VALVE TIMINGS

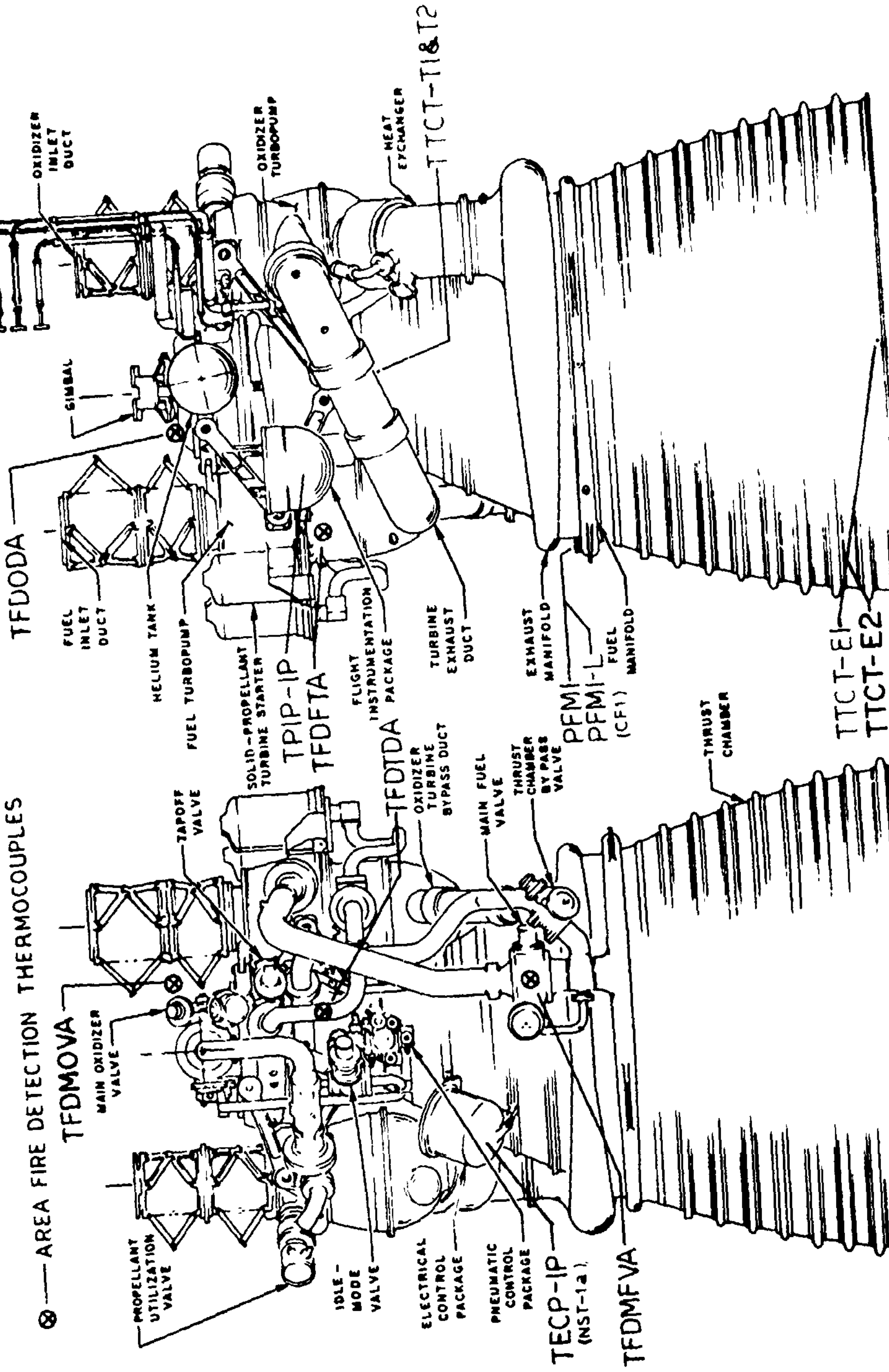
Test J4-1902-	Firing	Start																	
		Main Fuel Valve			Idle-Mode Oxidizer Valve			Hot Gas Tapoff Valve			Main Oxidizer Valve First Stage			Main Oxidizer Valve Second Stage			Thrust Chamber Bypass Valve		
		Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec	Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec	Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec	Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec	Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec	Time of Closing Signal	Valve Delay Time, sec	Valve Closing Time, sec
08	A	0	0.049	0.055	0	0.110	0.058	Data Not Recovered			20.875	0.080	0.033						
	Final Sequence	0	0.045	0.060	0	0.111	0.045				20.291	0.078	0.036						
11	A	0	0.051	0.060	0	0.126	0.041	10.248	0.160	0.074	10.248	0.081	0.026						
	B	0	0.049	0.058	0	0.115	0.042	19.998	0.154	0.078	19.998	0.080	0.025						
	Final Sequence	0	0.045	0.068	0	0.113	0.049	4.836	0.157	0.070	4.836	0.079	0.030						
12	A	0	0.051	0.054	0	0.113	0.045	10.121	0.163	0.075	10.121	0.084	0.028	22.835	0.168	0.813	22.835	0.209	0.842
	B	0	0.052	0.059	0	0.120	0.040	20.477	0.158	0.080	20.477	0.083	0.029	---	---	---	---	---	---
	C	0	0.053	0.060	0	0.122	0.038	20.145	0.160	0.078	20.145	0.080	0.030	32.740	0.174	0.840	32.740	0.202	0.963
	Final Sequence	0	0.051	0.068	0	0.124	0.049	4.934	0.153	0.074	4.934	0.080	0.035	---	---	---	---	---	---

Test J4-1902-	Firing	Shutdown														
		Main Oxidizer Valve			Hot Gas Tapoff Valve			Main Fuel Valve			Idle-Mode Oxidizer Valve			Thrust Chamber Bypass Valve		
		Time of Closing Signal	Valve Delay Time, sec	Valve Closing Time, sec	Time of Closing Signal	Valve Delay Time, sec	Valve Closing Time, sec	Time of Closing Signal	Valve Delay Time, sec	Valve Closing Time, sec	Time of Closing Signal	Valve Delay Time, sec	Valve Closing Time, sec	Time of Opening Signal	Valve Delay Time, sec	Valve Opening Time, sec
08	A	25.287	0.039	0.032	Data Not Recovered			25.287	0.072	0.258	25.287	0.070	0.155			
	Final Sequence	40.164	0.038	0.032				40.164	0.072	0.254	40.164	0.061	0.111			
11	A	16.048	0.039	0.029	16.048	0.074	0.208	16.048	0.073	0.253	16.048	0.068	0.145			
	B	15.030	0.039	0.029	15.030	0.073	0.201	15.030	0.080	0.254	15.030	0.065	0.142			
	Final Sequence	4.836	0.040	0.025	4.836	0.068	0.220	4.836	0.073	0.254	4.836	0.062	0.113			
12	A	24.534	0.069	0.157	24.534	0.073	0.209	24.534	0.082	0.263	24.534	0.079	0.160	24.534	0.250	0.192
	B	---	---	---	33.643	0.070	0.204	33.643	0.079	0.255	33.643	0.070	0.127	---	---	---
	C	40.923	0.089	0.161	40.923	0.073	0.225	40.923	0.06[illegible]	0.268	40.923	0.077	0.131	40.923	0.315	0.193
	Final Sequence	19.554	0.040	0.028	19.554	0.065	0.215	19.554	0.072	0.259	19.554	0.062	0.118	---	---	---

Notes
1. All valve signal times are referenced to t_0.
2. Valve delay time is the time required for initial valve moment after the valve "open" or "closed" solenoid has been energized.
3. Final sequence check is conducted without propellants and within 12 hr before testing
4. Data are reduced from oscillogram

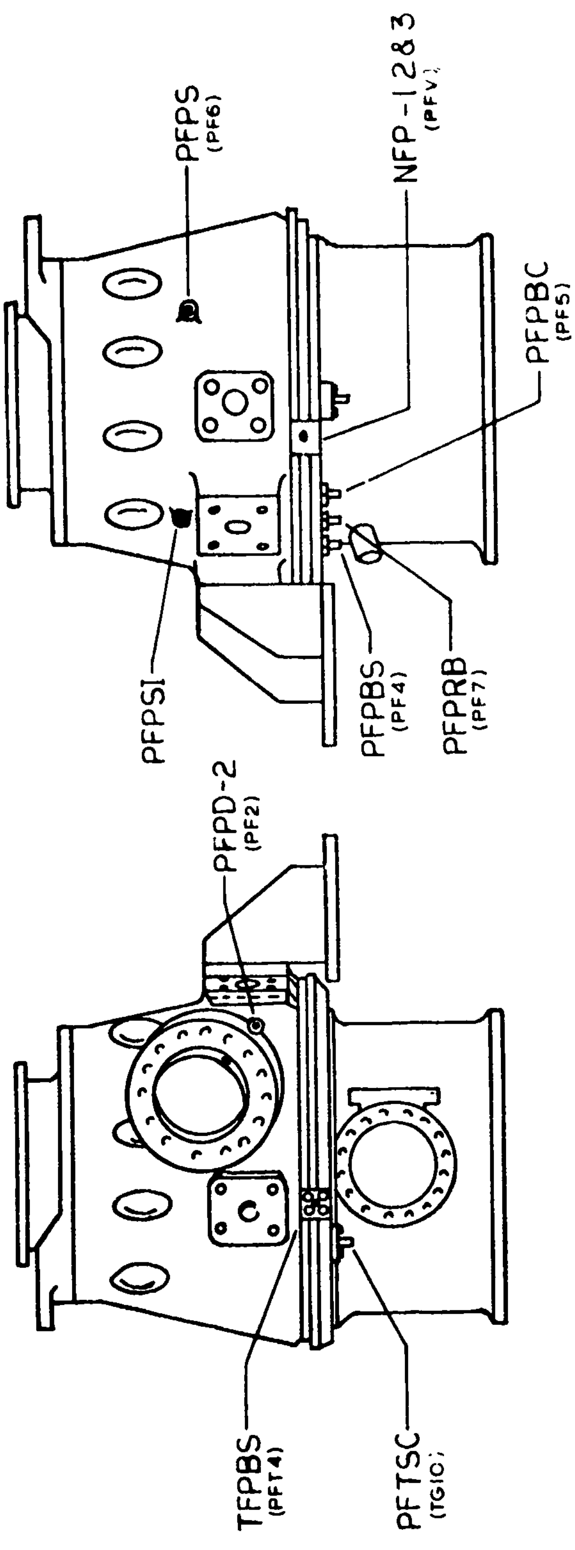
APPENDIX III
INSTRUMENTATION

The instrumentation for AEDC tests J4-1902-08, -11, and -12 is tabulated in Table III-1. The location of selected major engine instrumentation is shown in Fig III-1.

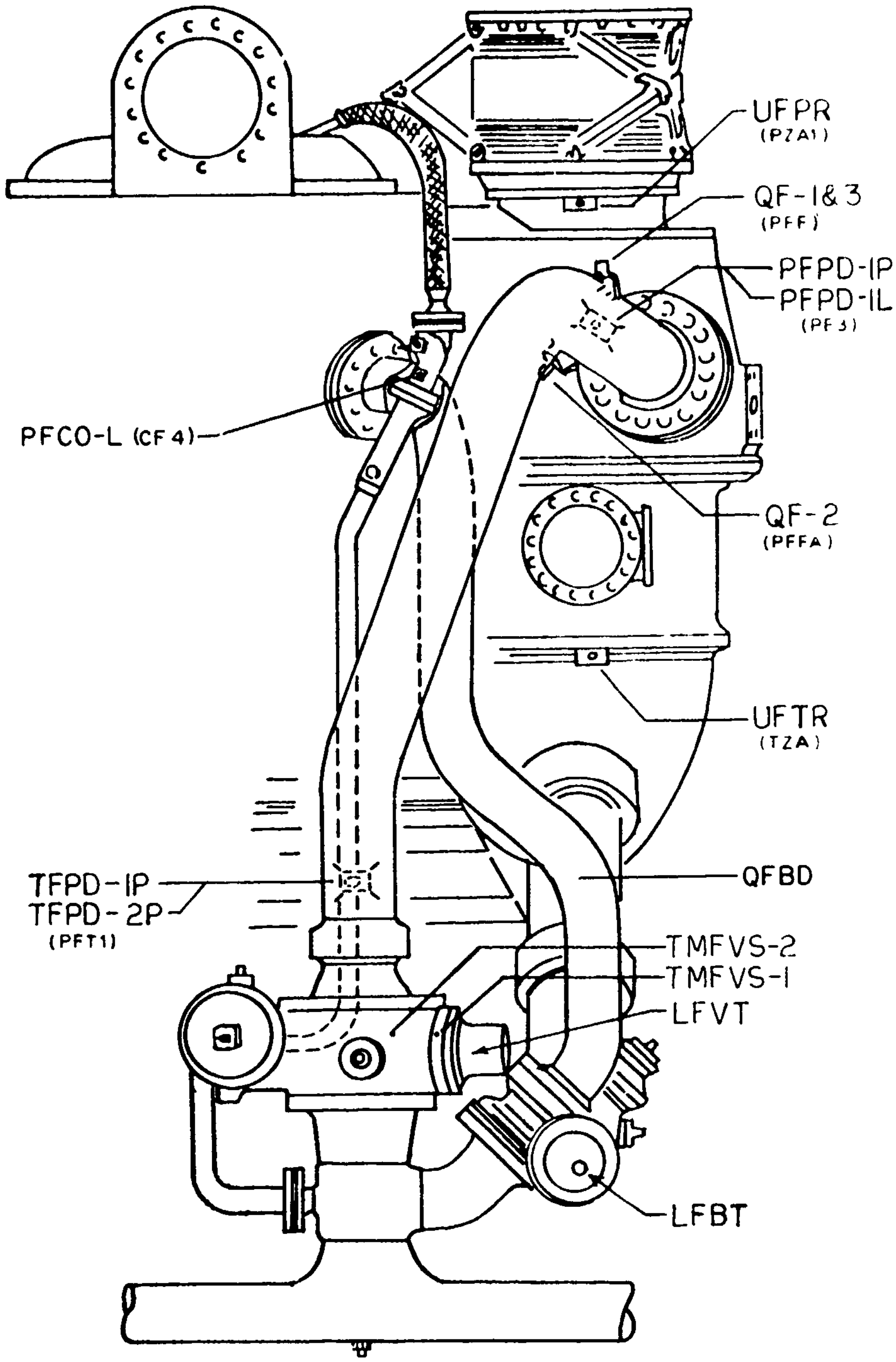


a. General Arrangement

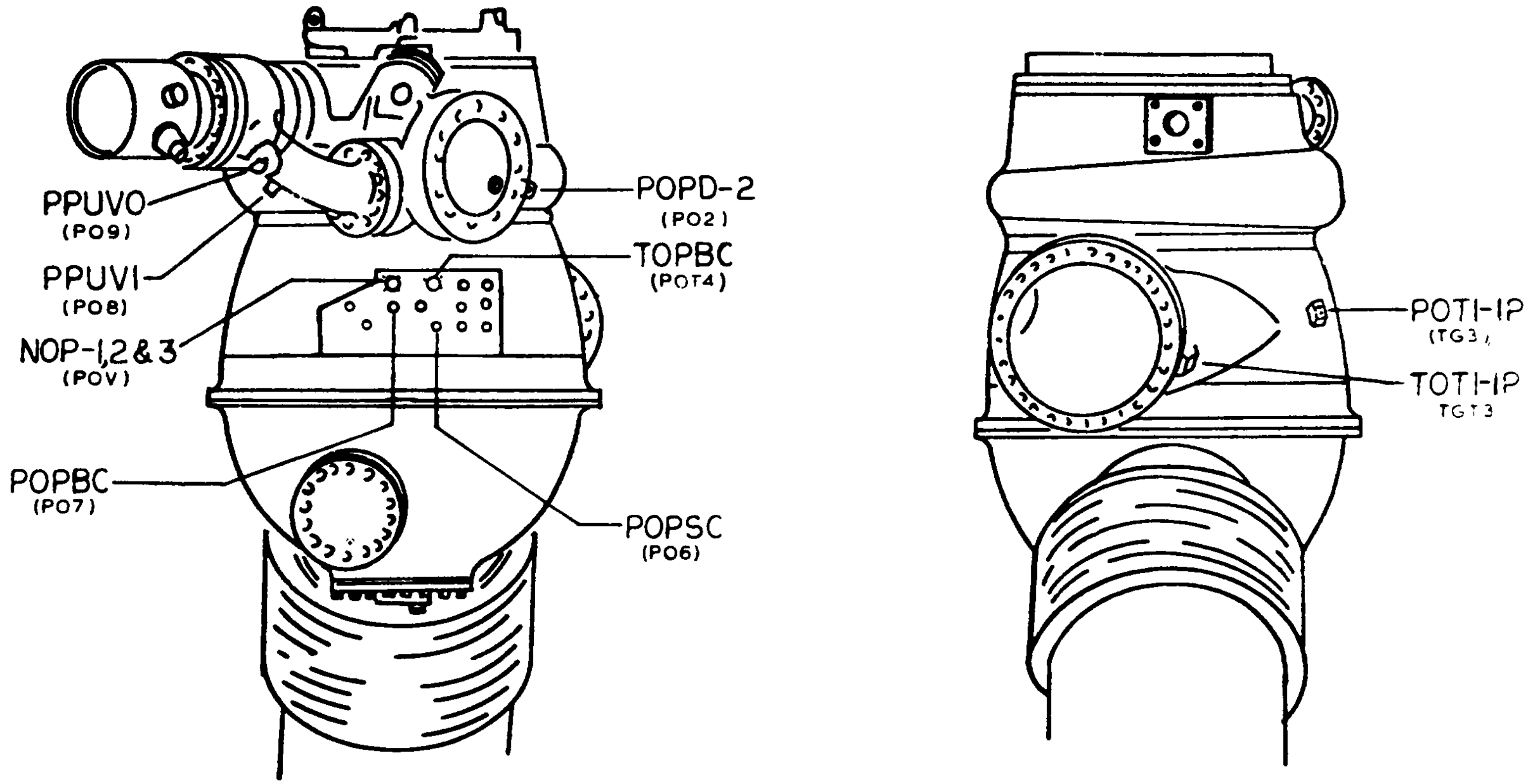
Fig. III-1 Selected Sensor Locations



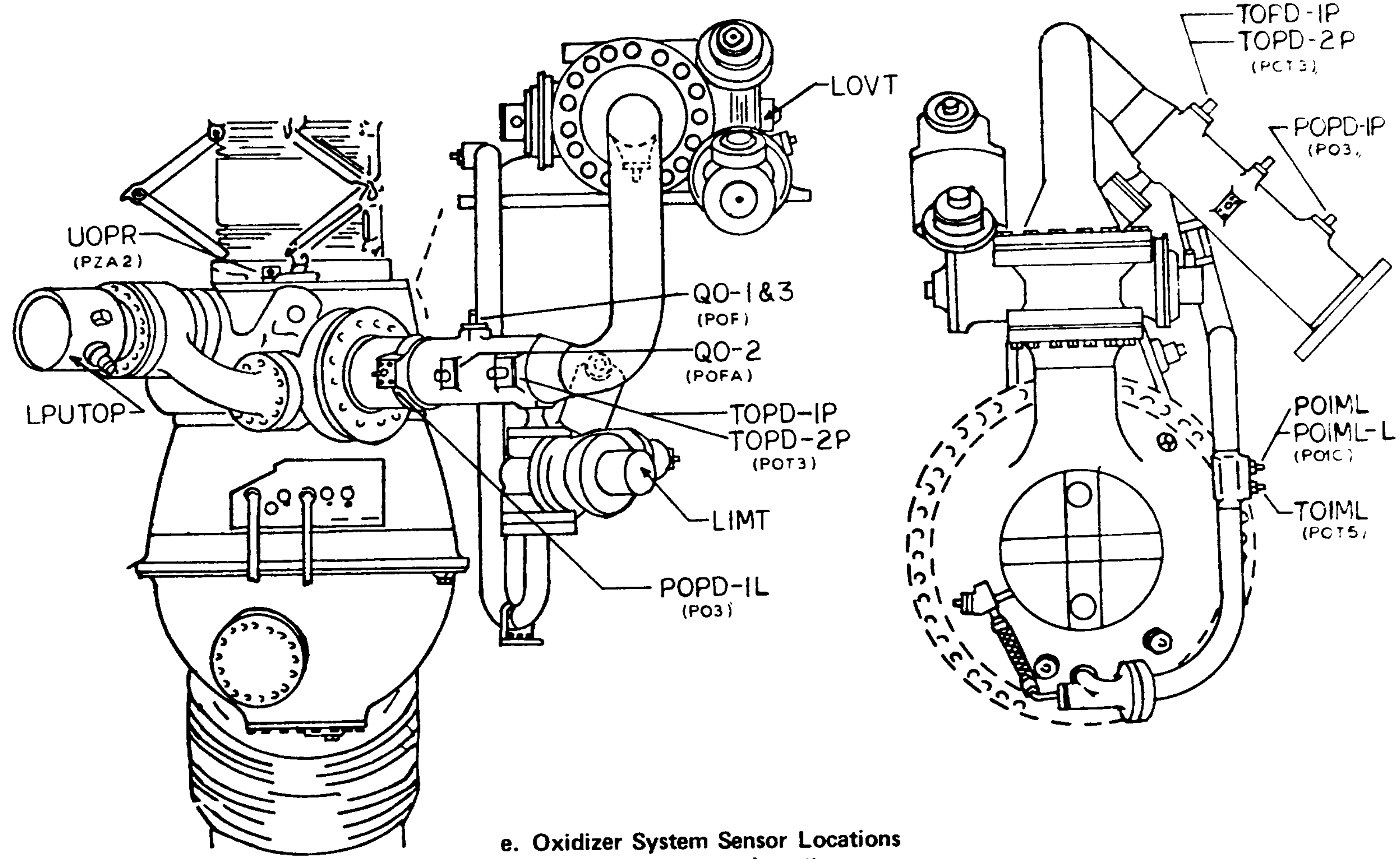
b. Fuel Turbopump Sensor Locations
Fig. III-1 (Continued)



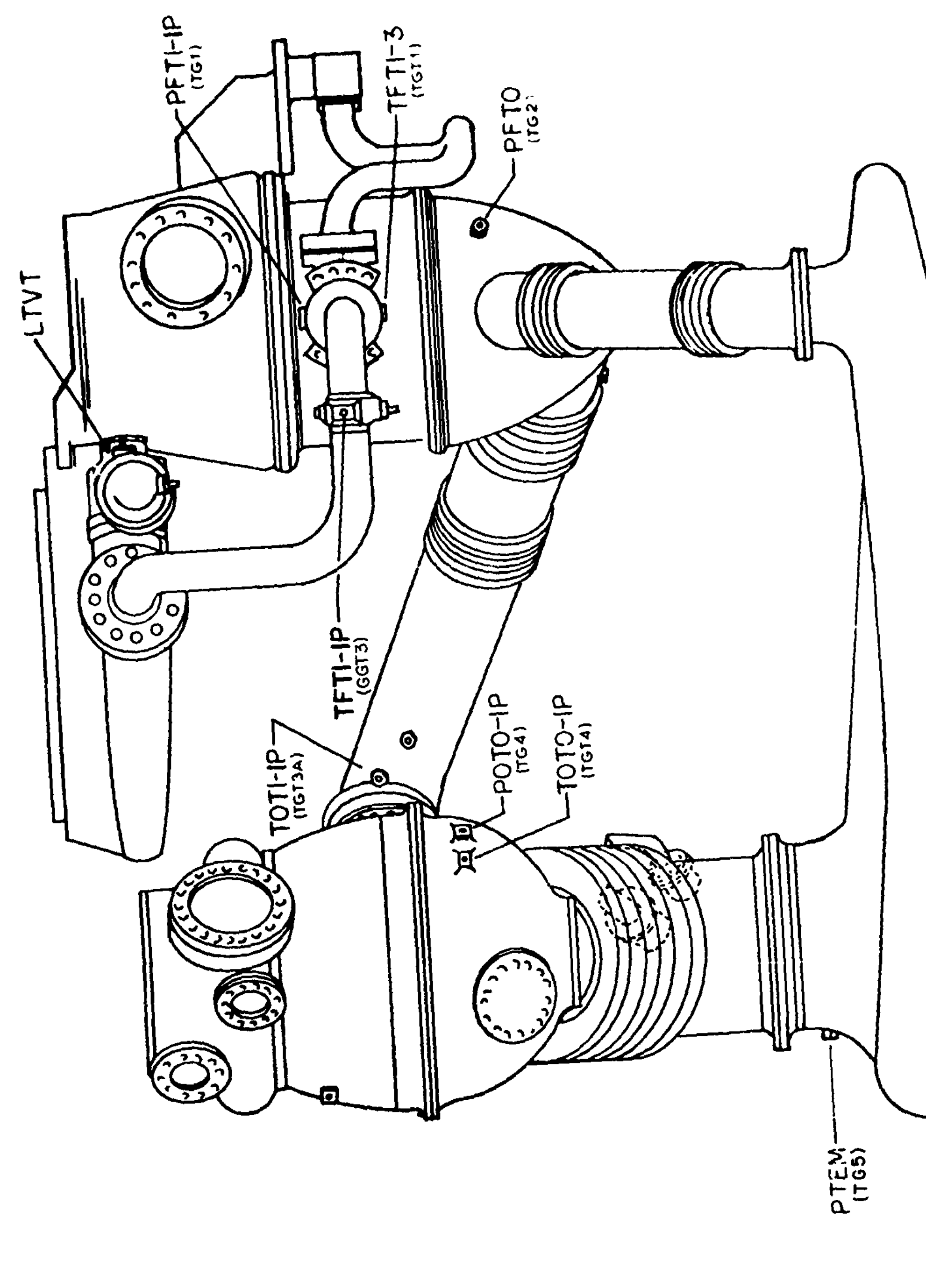
c. Fuel System Sensor Locations
Fig. III-1 (Continued)



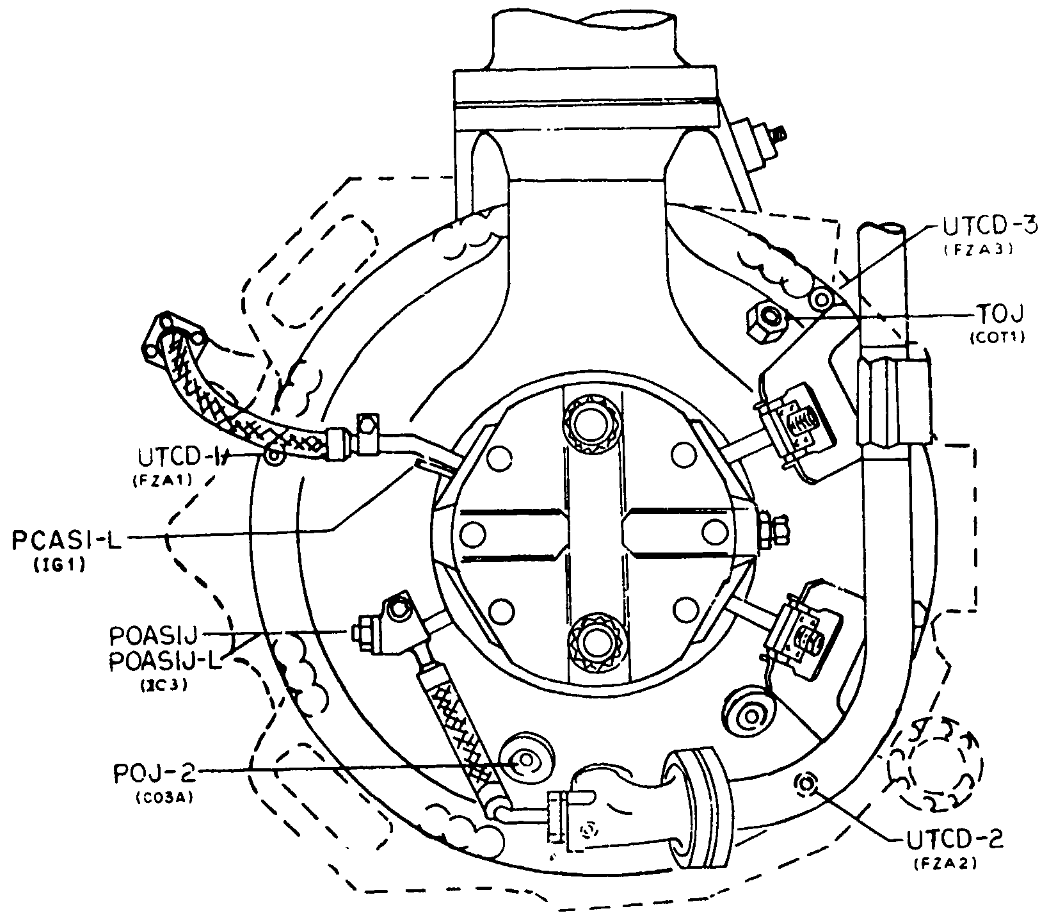
d. Oxidizer Turbopump Sensor Locations
Fig. III-1 (Continued)



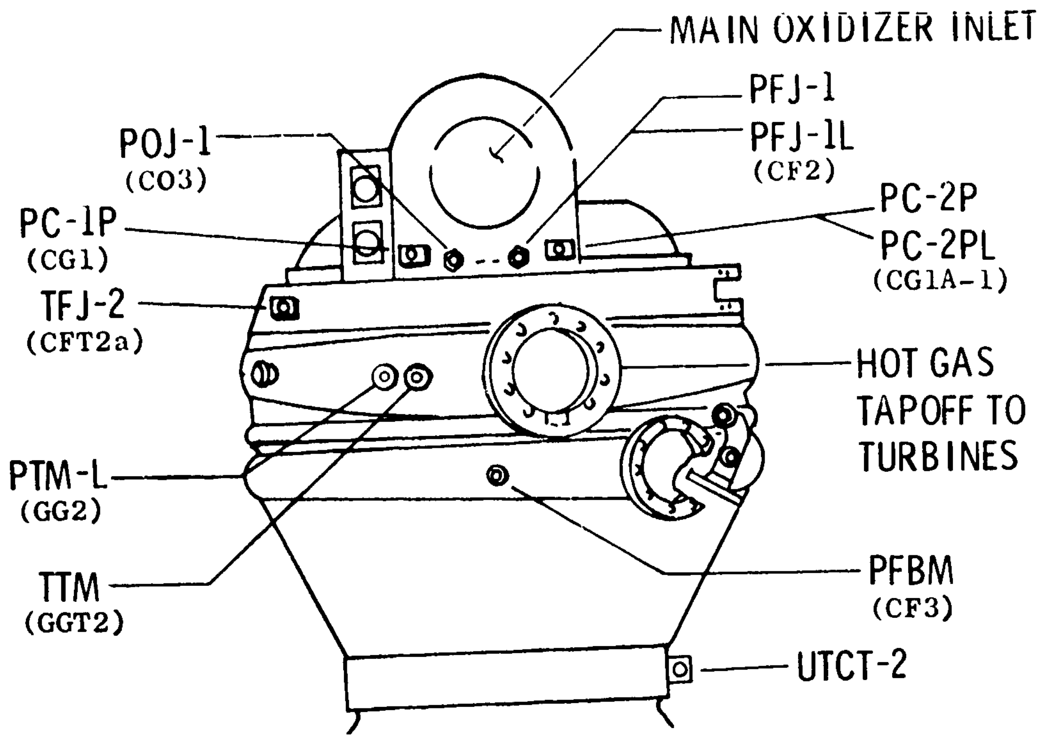
e. Oxidizer System Sensor Locations
Fig. III-1 (Continued)

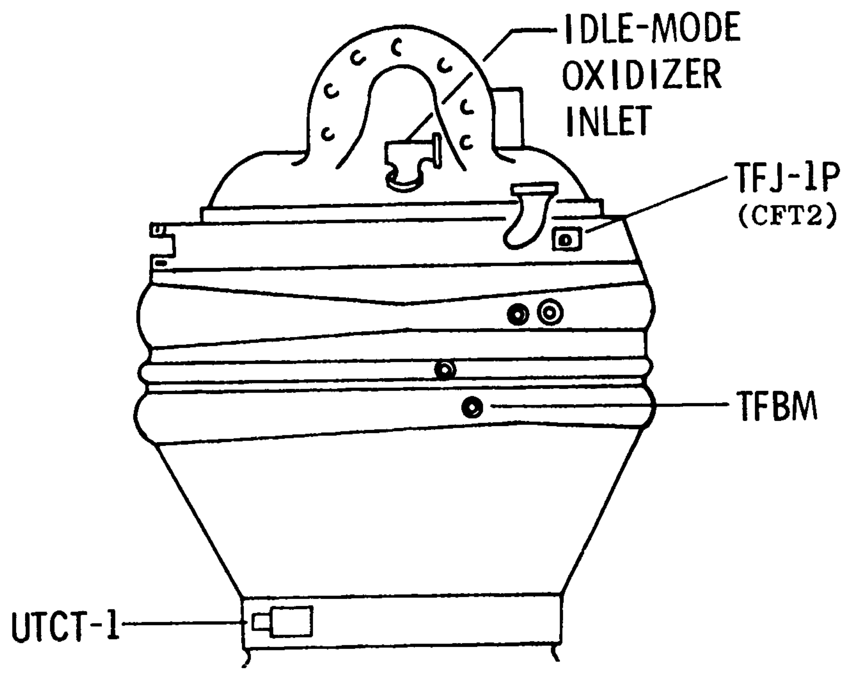


f. Turbine Exhaust Systems Sensor
Fig. III-1 (Continued)

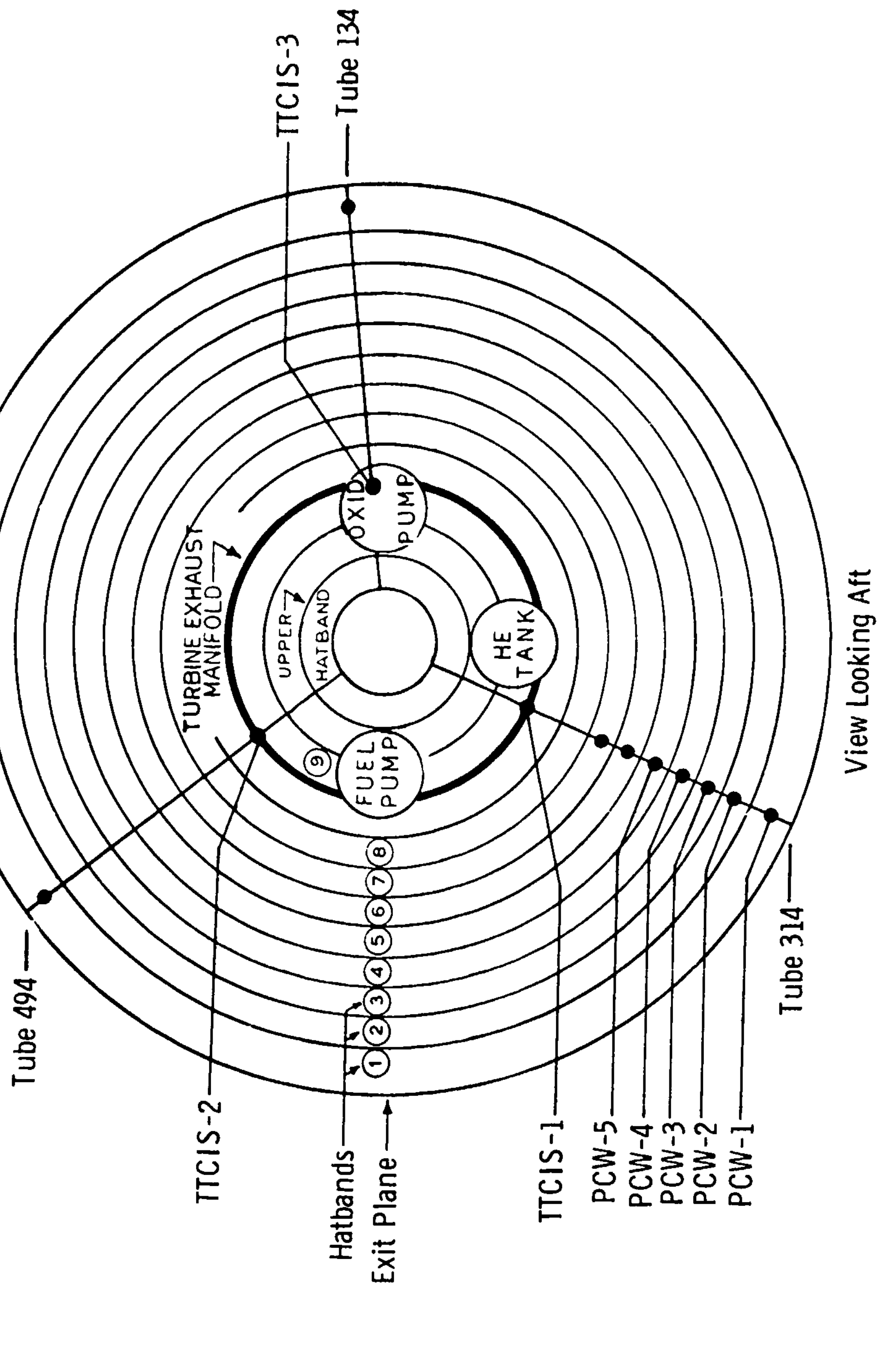


g. Thrust Chamber Injector Sensor Locations
Fig. III-1 (Continued)

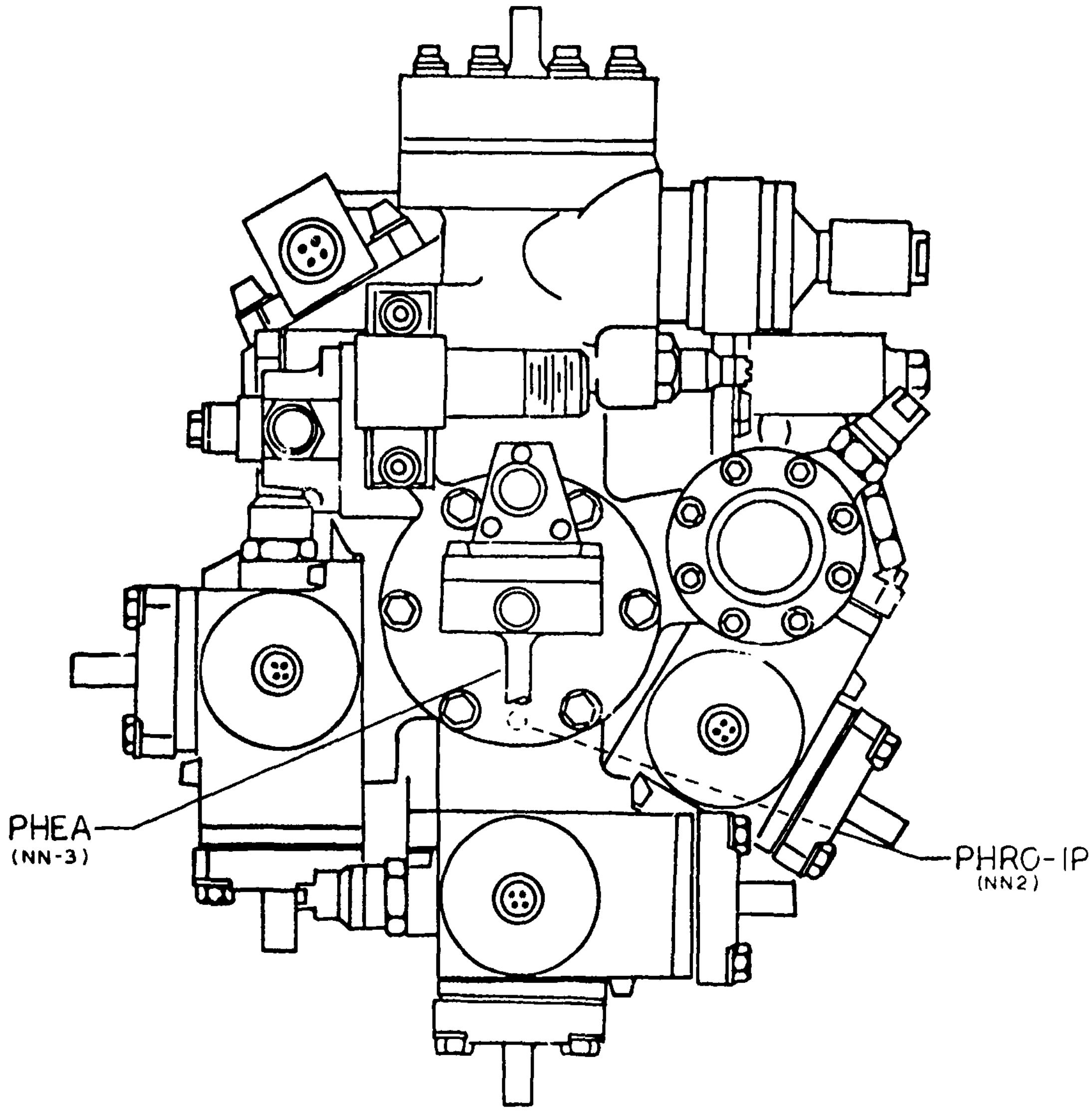




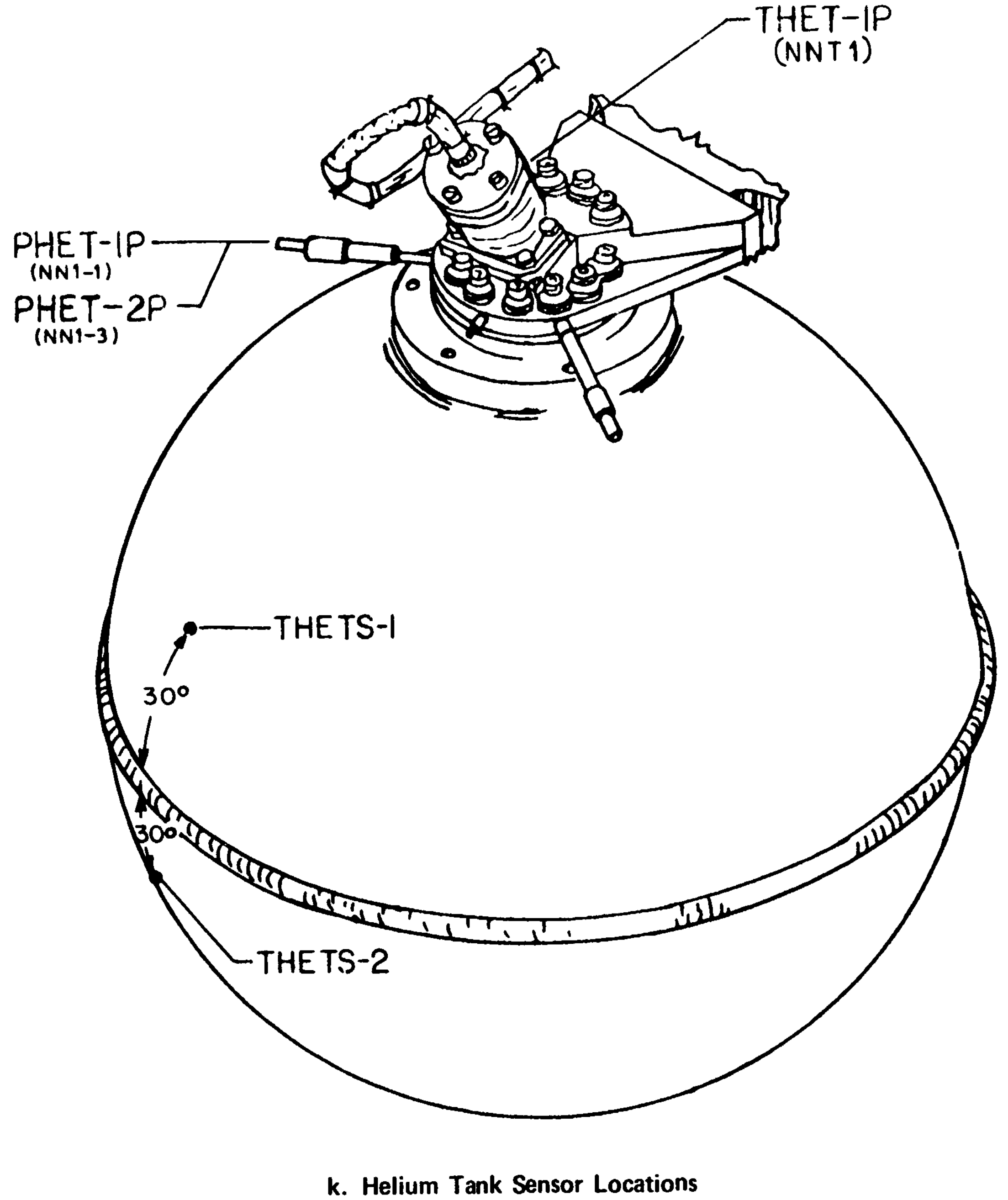
h. Thrust Chamber Sensor Locations
Fig. III-1 (Continued)



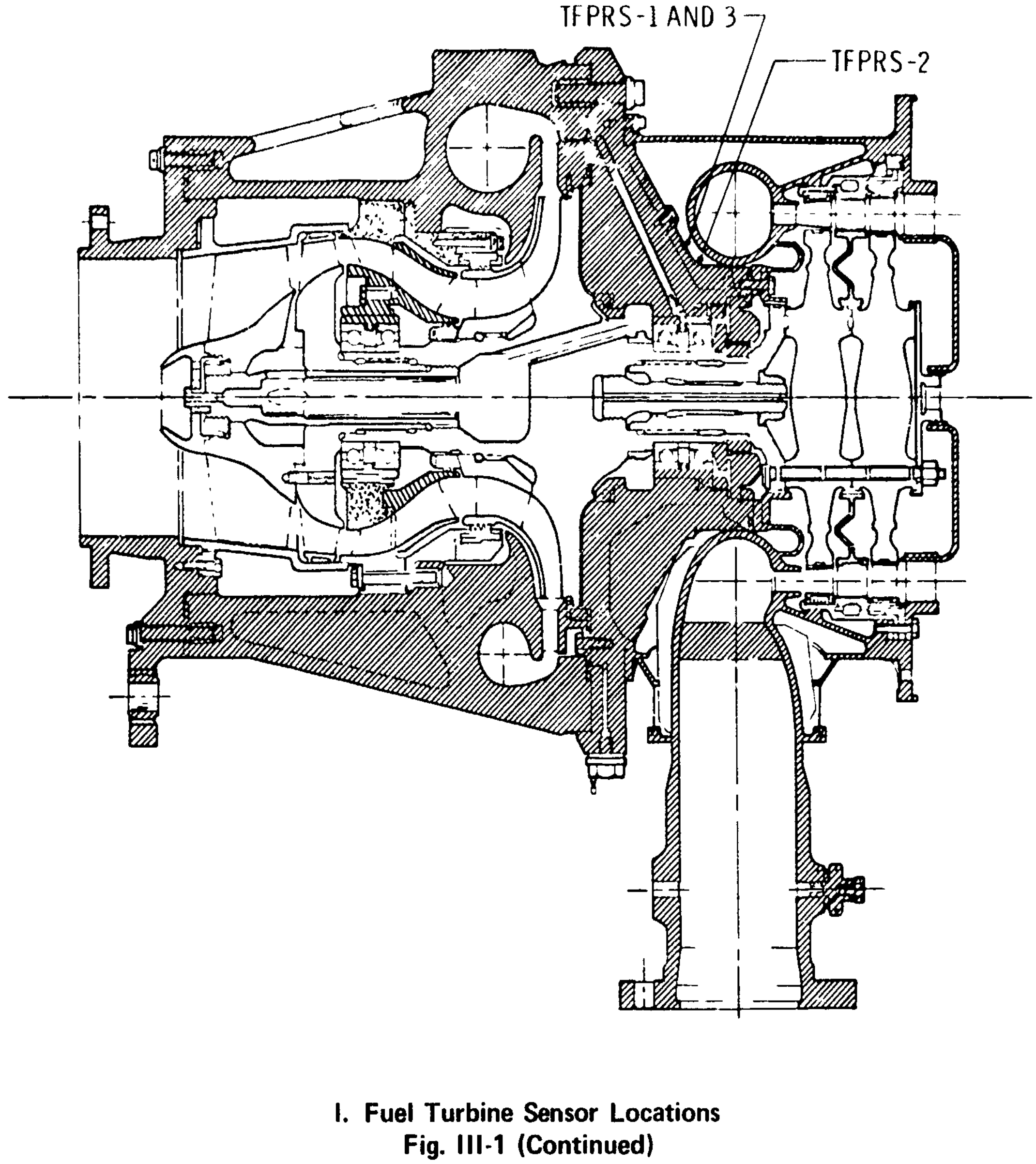
i. Thrust Chamber Instrumentation
Fig. III-1 (Continued)



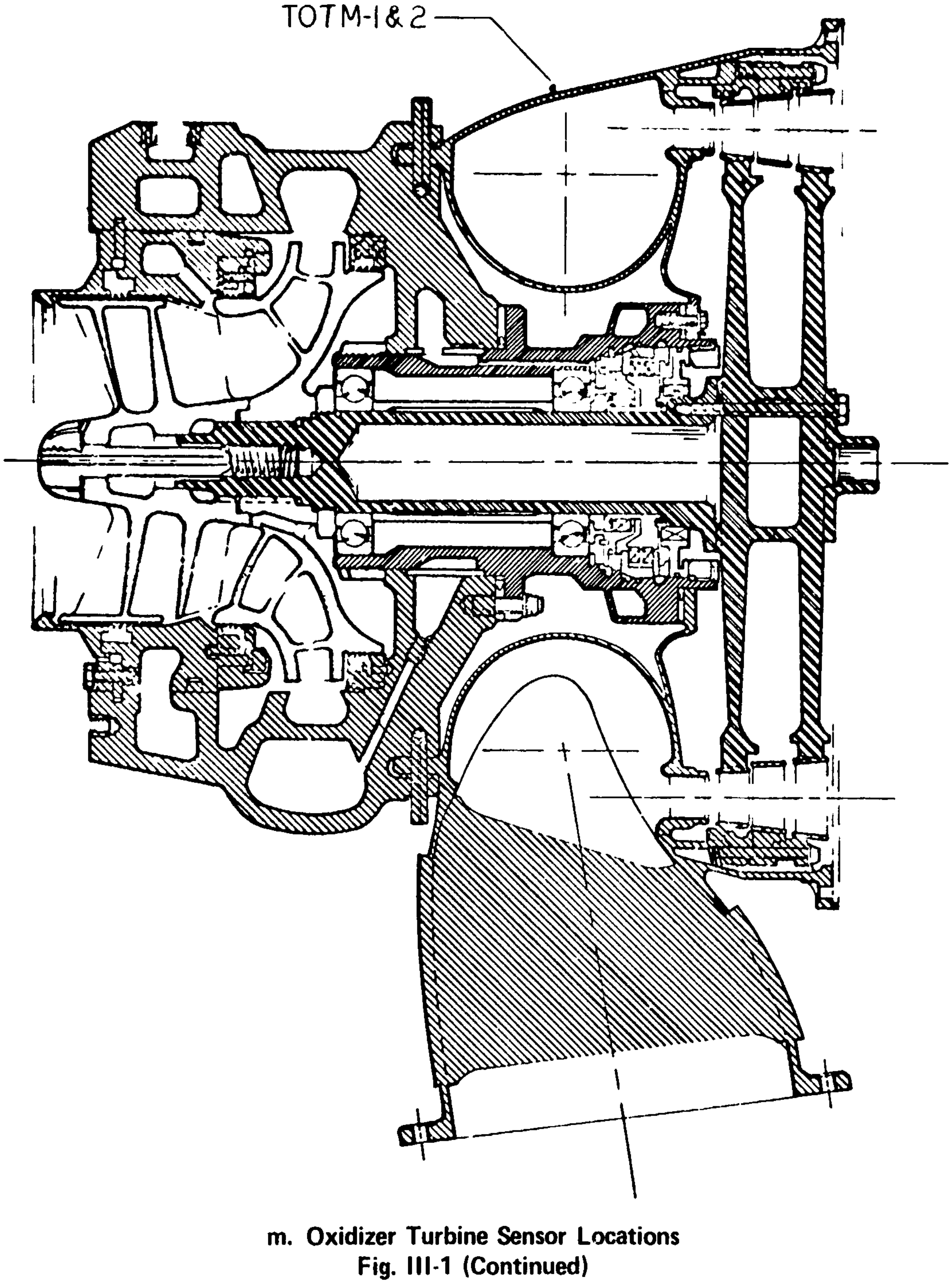
j. Pneumatic Control Package Sensor Locations
Fig. III-1 (Continued)



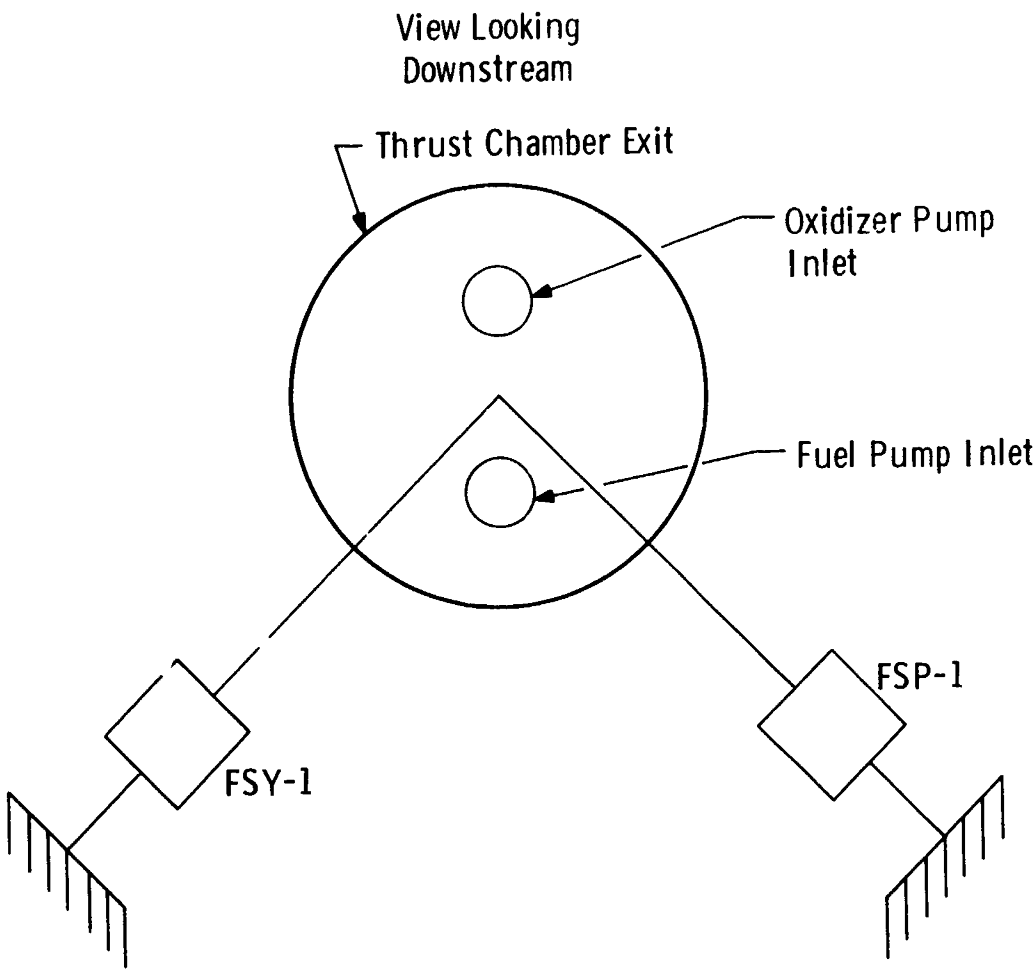
k. Helium Tank Sensor Locations
Fig. III-1 (Continued)



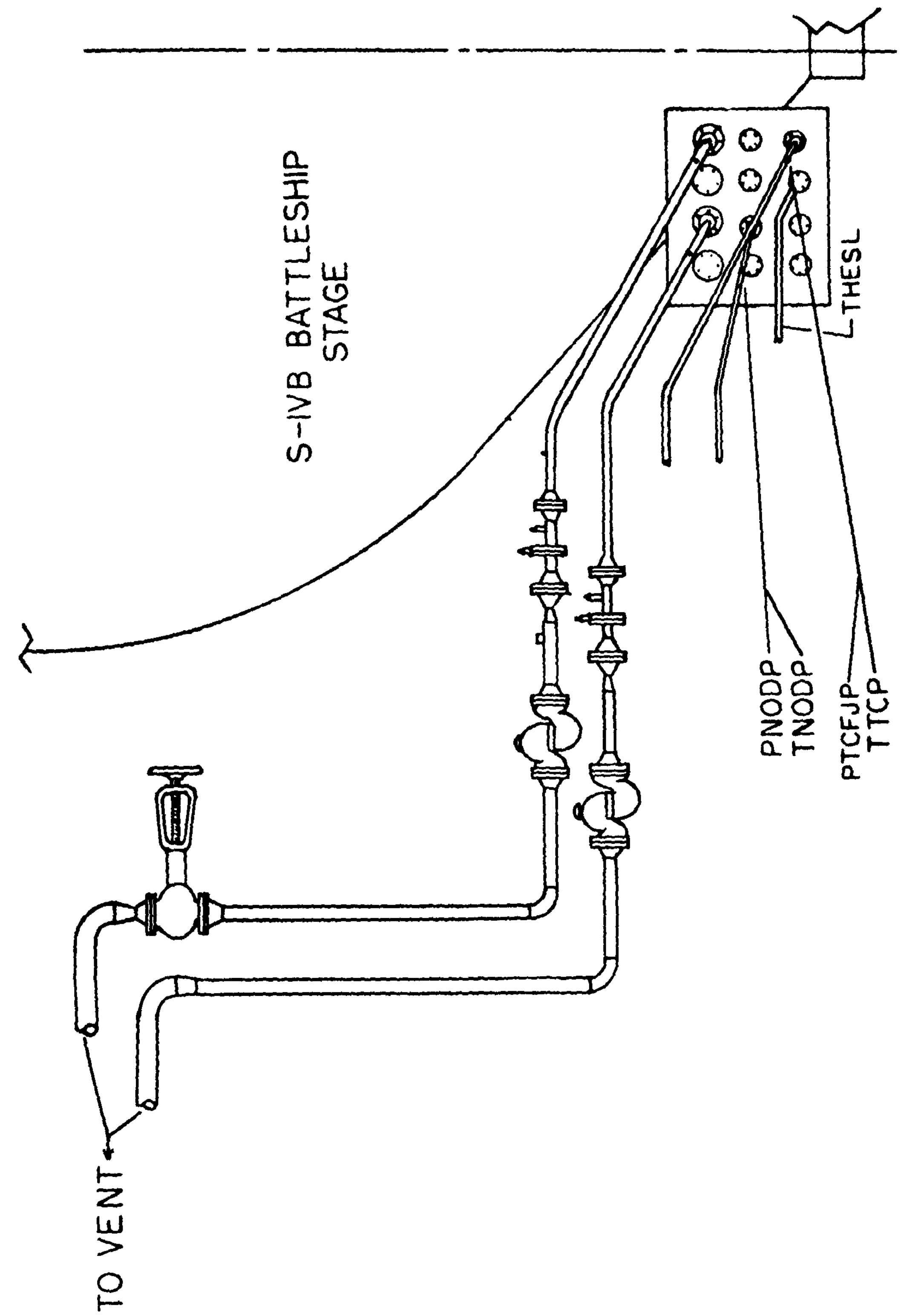
I. Fuel Turbine Sensor Locations
Fig. III-1 (Continued)



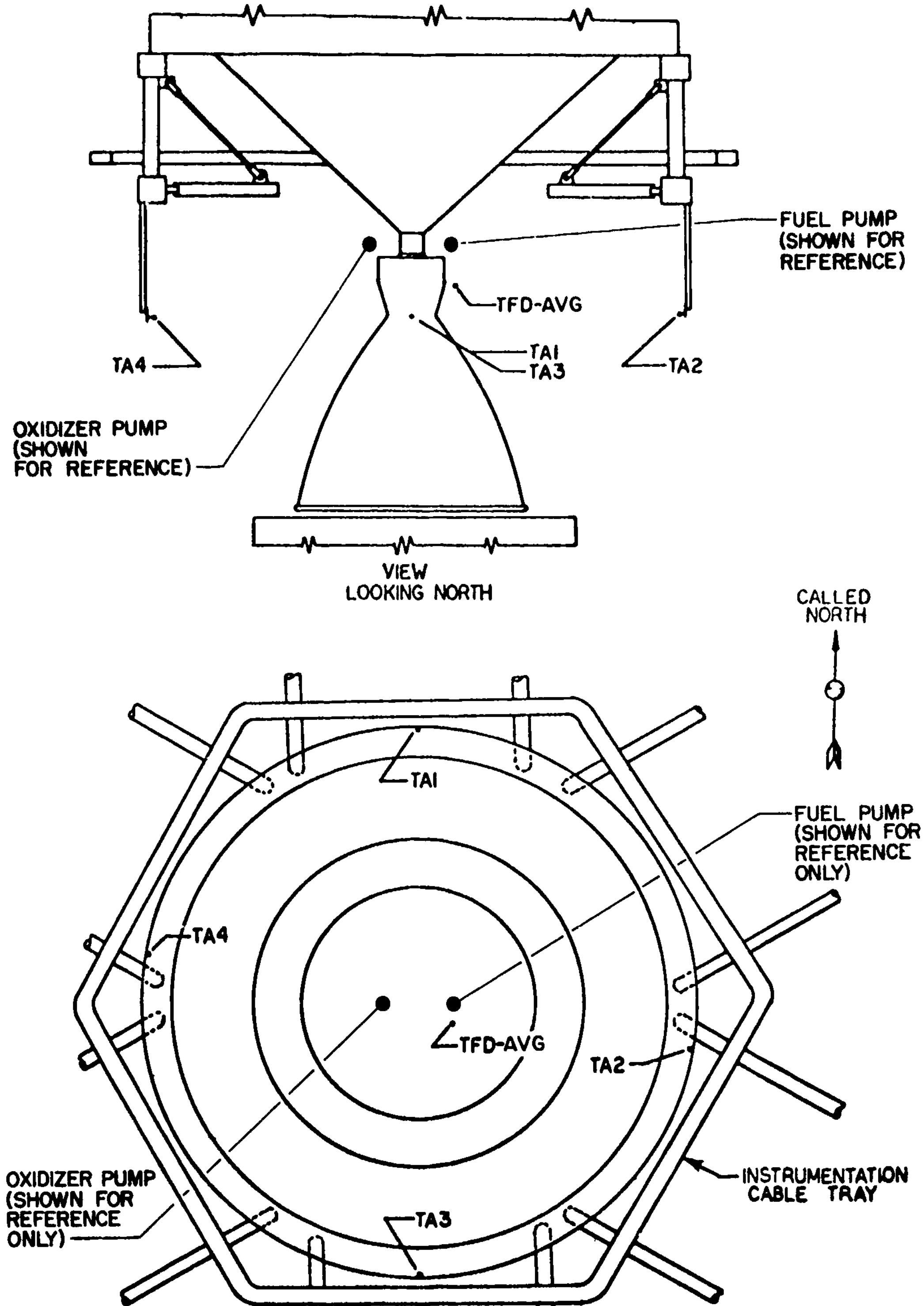
m. Oxidizer Turbine Sensor Locations
Fig. III-1 (Continued)



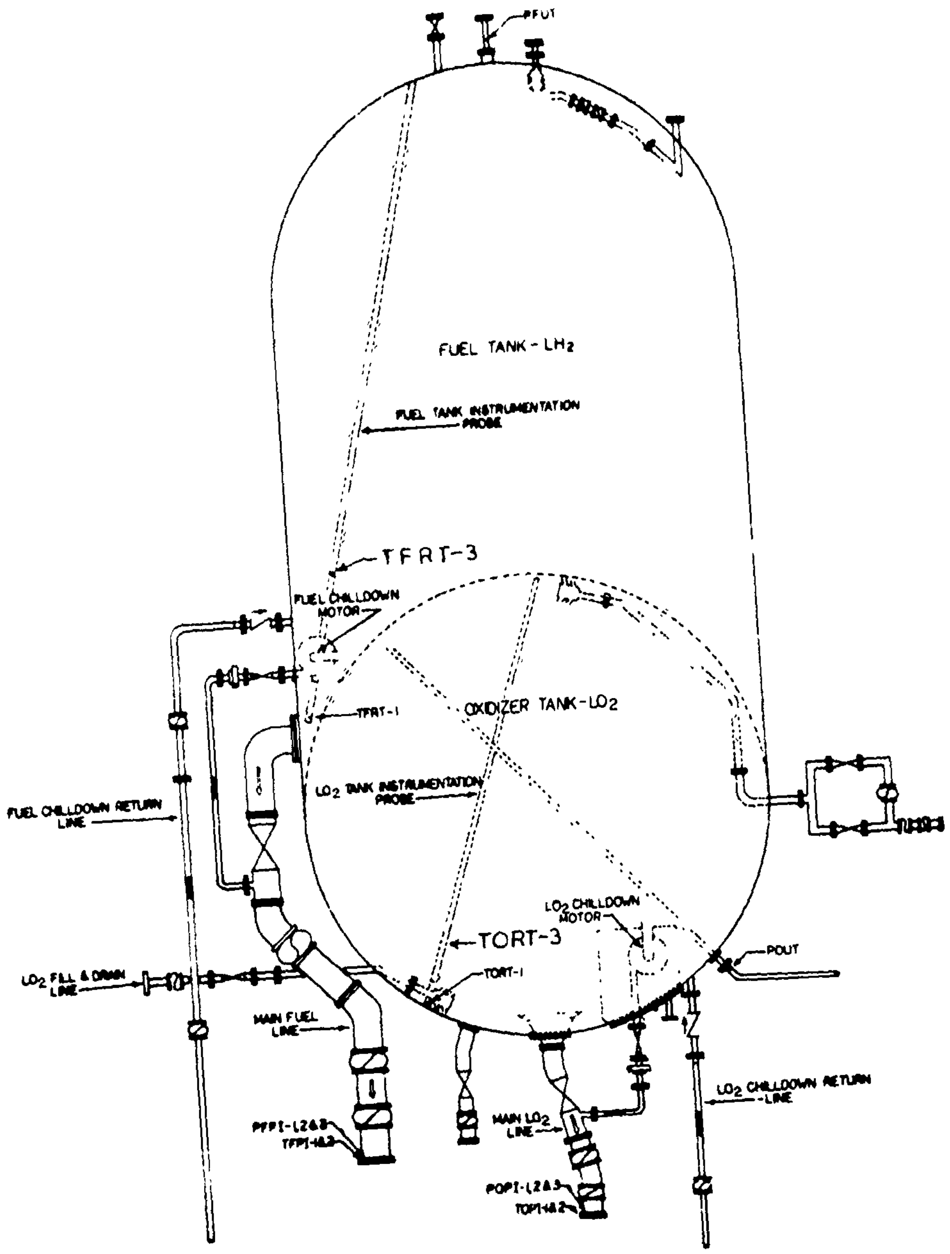
n. S[illegible] [illegible]oad Forces Sensor Locations
[illegible]g. III-1 (Continued)



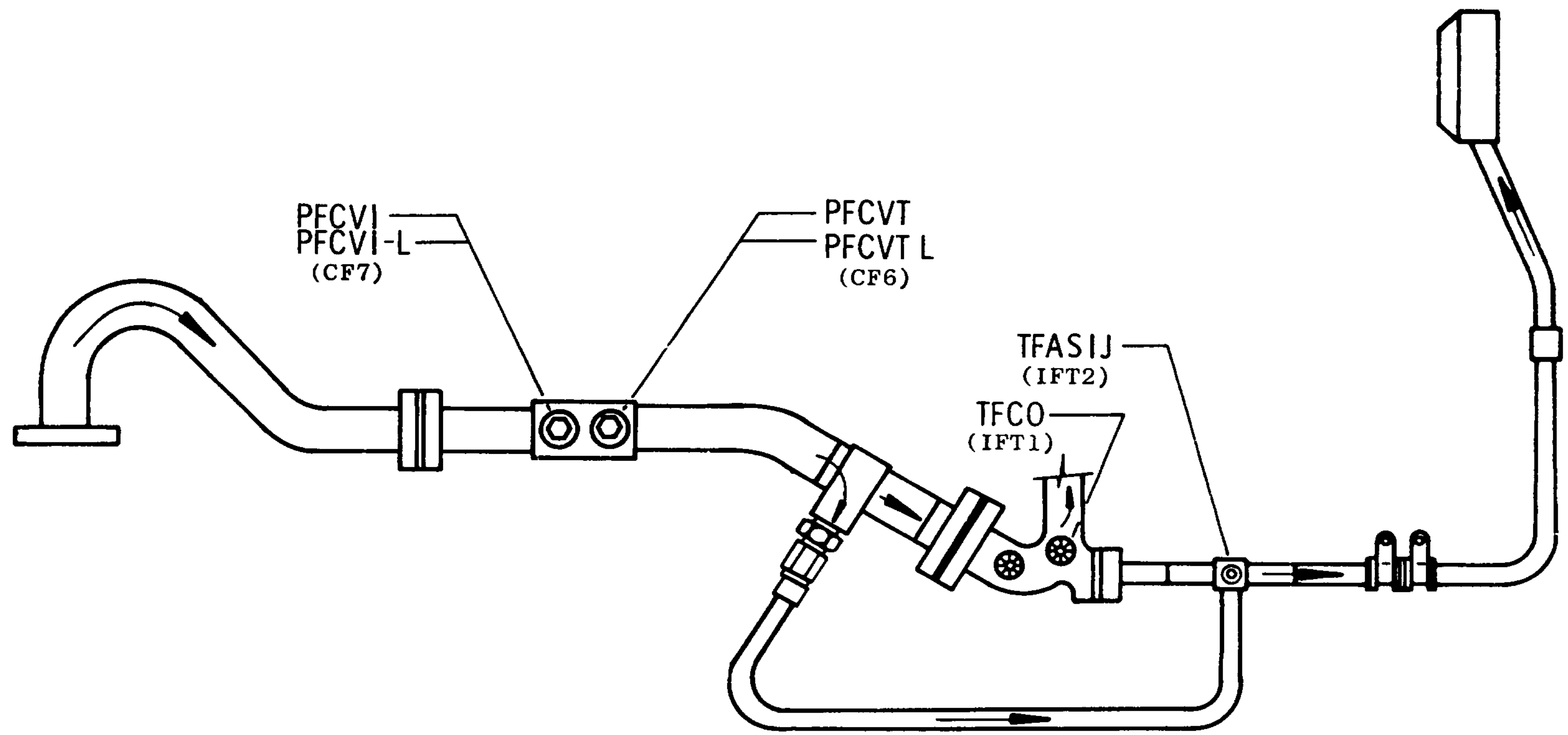
a. Customer Connect Panel Sensor Locations
Fig. III-1 (Continued)



p. Test Cell Ambient Temperature Sensor Locations
Fig. III-1 (Continued)



q. S-IVB Battleship Sensor Locations
Fig. III-1 (Continued)



r. Augmented Spark Igniter/Film Coolant Fuel Line Assembly Instrumentation
Fig. III-1 (Concluded)

TABLE III-1
INSTRUMENTATION LIST

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Current		amp						
ICC	Control		0 to 30	x					
IIC	Ignition		0 to 30	x					
	Event								
EASIS-1	Augmented Spark Igniter No. 1 Spark		On/Off					x	
EASIS-2	Augmented Spark Igniter No. 2 Spark		On/Off					x	
EECL	Engine Cutoff Lockin		On/Off	x		x		x	
EECO	Engine Cutoff Signal		On/Off	x		x		x	
EER	Engine Ready Signal		On/Off					x	
EES	Engine Start Command		On/Off	x		x		x	
EESCO	Programmed Duration Cutoff		On/Off					x	
EFBVO	Fuel Bleed Valve Open Limit		On/Off					x	
EFPCO	Fuel Pump Overspeed Cutoff		On/Off					x	
EFPVC	Fuel Prevalve Closed Limit		On/Off	x				x	
EFPVO	Fuel Prevalve Open Limit		On/Off	x				x	
EHCS	Helium Control Solenoid Energized		On/Off	x	x	x		x	
EHGTC	Hot Gas Tapoff Valve Closed Limit		On/Off					x	
EHGTO	Hot Gas Tapoff Valve Open Limit		On/Off					x	
EID	Ignition Detected		On/Off	x		x		x	
EIDA-1	Ignition Detect Amplifier No. 1		On/Off					x	
EIDA-2	Ignition Detect Amplifier No. 2		On/Off					x	
EIMCS	Idle-Mode Control Solenoid Energized		On/Off	x		x		x	
EIMVC	Idle-Mode Valve Closed Limit		On/Off					x	
EIMVO	Idle-Mode Valve Open Limit		On/Off					x	
EMCL	Main-Stage Cutoff Lockin		On/Off	x		x		x	
EMCO	Main-Stage Cutoff Signal		On/Off	x		x			
EMCS	Main-Stage Control Solenoid Energized		On/Off	x		x		x	
EMFVC	Main Fuel Valve Closed Limit		On/Off					x	
EMFVO	Main Fuel Valve Open Limit		On/Off					x	
EMOVC	Main Oxidizer Valve Closed Limit		On/Off					x	

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Event								
EMOVO	Main Oxidizer Valve Open Limit		On/Off					x	
FMP-1	No. 1 Main Stage "OK" Pressurized		On/Off	x		x		x	
EMPCO	Main-Stage Pressure Cutoff Signal		On/Off					x	
FMS	Main-Stage Start Signal		On/Off					x	
FMSCO	Main-Stage Programmed Duration Cutoff		On/Off					x	
FMSS	Main-Stage Start Solenoid Energized		On/Off	x	x	x		x	
EOBVO	Oxidizer Bleed Valve Open Limit		On/Off					x	
EOCO	Observer Cutoff Signal		On/Off					x	
EOPCO	Oxidizer Pump Overspeed Cutoff Signal		On/Off					x	
EOPVC	Oxidizer Prevalve Closed Limit		On/Off	x				x	
EOPVO	Oxidizer Prevalve Open Limit		On/Off	x				x	
EOTCO	Fuel Turbine Over-temperature Cutoff		On/Off					x	
ERASIS-1	Augmented Spark Igniter No. 1 Spark Rate		On/Off			x			
ERASIS-2	Augmented Spark Igniter No. 2 Spark Rate		On/Off			x			
ESTCO	Start "OK" Timer Cutoff Signal		On/Off					x	
ETCBC	Thrust Chamber Bypass Valve Closed		On/Off					x	
ETCBO	Thrust Chamber Bypass Valve Open		On/Off					x	
EVSC-1	Vibration Safety Counts No. 1		On/Off			x			
EVSC-2	Vibration Safety Counts No. 2		On/Off			x			
EVSC-3	Vibration Safety Counts No. 3		On/Off			x			
	Flows		gpm						
QF-1	Engine Fuel	PFF	0 to 11,000	x					x(1)
QF-2	Engine Fuel	PFFa	0 to 11,000	x	x	x			
QF-3	Engine Fuel	PFF	0 to 11,000			x			
QO-1	Engine Oxidizer	POF	0 to 3,600	x					
QO-2	Engine Oxidizer	POFa	0 to 3,600	x	x	x			
QO-3	Engine Oxidizer	POF	0 to 3,600			x			
	Forces		lbf						
FSP-1	Side Load (Pitch)		±20,000	x		x			
FSY-1	Side Load (Yaw)		±20,000	x		x			

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No	Range	Digital Data System	Magnetic Tape	Oscillo-graph	Strip Chart	Event Recorder	X-Y Plotter
	Heat Flux		$\frac{w}{sr\text{-}cm^2}$						
RTCEP (1)	Radiation Thrust Chamber Exhaust Plume		0-4	x					
	Position		Percent Open						
LFBT	Thrust Chamber Bypass Valve		0 to 100	x		x			
LFVT	Main Fuel Valve		0 to 100	x		x			
LIMT	Idle-Mode/Augmented Spark Igniter Oxidizer Valve		0 to 100	x		x			
LOVT	Main Oxidizer Valve		0 to 100	x		x			
LPUTOP	Propellant Utilization Valve		5 volts	x		x	x		
LTVT	Hot Gas Tapoff Valve		0 to 100	x		x			
	Pressure		psia						
PA-1	Test Cell		0 to 0.5	x					
PA-2	Test Cell		0 to 1.0	x					
PA-3	Test Cell		0 to 5.0	x		x	x		
PC-1P	Thrust Chamber	CG1	0 to 1500	x					
PC-2P	Thrust Chamber	CG1a-1	0 to 1500	x		x	x		
PC-2PL	Thrust Chamber	CG1a-1	0 to 50	x		x			
PCASI 1	Augmented Spark Igniter Chamber		0 to 1500	x					
PCASI-L	Augmented Spark Igniter Chamber		0 to 500	x		x			
PFBM	Thrust Chamber Bypass Manifold	CF3	0 to 1500	x					
PFCO (1)	Film Coolant Orifice	CF4	0 to 2000	x					
PFCO-L	Film Coolant Orifice	CF4	0 to 500	x					
PFCVI	Film Coolant Venturi Inlet	CF7	0 to 2000	x					
PFCVI-L	Film Coolant Venturi Inlet	CF7	0 to 50	x					
PFCVT	Film Coolant Venturi Throat	CF6	0 to 2000	x					
PFCVT-L	Film Coolant Venturi Throat	CF6	0 to 50	x					
PFJ-1	Fuel Injection	CF2	0 to 500	x		x			
PFJ-1L	Fuel Injection	CF2	0 to 50	x					
PFMI	Fuel Jacket Manifold Inlet	CF1	0 to 2000	x					

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillo-graph	Strip Chart	Event Recorder	X-Y Plotter
	Pressure		psia						
PFMI-L	Fuel Jacket Mani-fold Inlet	CF1	0 to 50	x					
PFPBC	Fuel Pump Balance Piston Cavity	PF5	0 to 2000	x		x	x		
PFPBS	Fuel Pump Balance Piston Sump	PF4	0 to 1000	x		x	x[1]		
PFPD-1L	Fuel Pump Discharge	PF3	0 to 50	x					
PFPD-1P	Fuel Pump Discharge	PF3	0 to 2500	x			x		
PFPD 2	Fuel Pump Discharge	PF2	0 to 500	x	x	x			x(1)
PFPI-1	Fuel Pump Inlet	PF1	0 to 100	x					x
PFPI-2	Fuel Pump Inlet		0 to 100	x					x
PFPI-3	Fuel Pump Inlet	PF1a	0 to 100	x	x	x			
PFPRB	Fuel Pump Rear Bearing Coolant	PF7	0 to 1000	x			x(1)		
PFPS	Fuel Pump Inter-stage	PF6	0 to 200	x		x			
PFPSI	Fuel Pump Shroud Inlet		0 to 2500	x					
PFTI-1P	Fuel Turbine Inlet	TG1	0 to 1000	x		x			
PFTO	Fuel Turbine Outlet	TG2	0 to 200	x					
PFTSC	Fuel Turbine Seal Cavity	TG10	0 to 500	x					
PFUT	Fuel Ullage Tank		0 to 100	x					
PFVC	Fuel Repressurization at Customer Connect Panel		0 to 2000	x					
PFVI	Fuel Repressurization Nozzle Inlet	KHF1	0 to 2000	x					
PFVL	Fuel Repressurization Nozzle Throat	KHF2	0 to 1000	x					
PHEA	Helium Accumulator	NN3	0 to 750	x					
PHES	Helium Supply		0 to 5000	x					
PHET-1P	Helium Tank	NN1 -1	0 to 5000	x					x
PHET-2P	Helium Tank	NN1 -3	0 to 5000	x					
PHRO-1P	Helium Regulator Outlet	NN2	0 to 750	x					
PNODP	Oxidizer Dome Purge at Customer Connect Panel		0 to 750	x					

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Pressure		psia						
POASIJ	Augmented Spark Igniter Oxidizer Injection	IO3	0 to 1500	x		x			
POASIJ-L	Augmented Spark Igniter Oxidizer Injection	IO3	0 to 50	x					
POIML	Oxidizer Idle Mode Line	PO10	0 to 2000	x					
POIML-L	Oxidizer Idle Mode Line	PO10	0 to 50	x					
POJ-1	Oxidizer Injection	CO3	0 to 500	x					
POJ-2	Oxidizer Injection	CO3a	0 to 1500	x		x			
POJ-3	Oxidizer Injection Manifold	CO3b	0 to 5000		x				
POPBC	Oxidizer Pump Bearing Coolant	PO7	0 to 500	x			x		
POPD-1L	Oxidizer Pump Discharge	PO3	0 to 50	x					
POPD-1P	Oxidizer Pump Discharge	PO3	0 to 2500	x					
POPD-2	Oxidizer Pump Discharge	PO2	0 to 500	x	x	x			
POPI-1	Oxidizer Pump Inlet	PO1	0 to 100	x					x
POPI-2	Oxidizer Pump Inlet		0 to 100	x					x
POPI-3	Oxidizer Pump Inlet	PO1a	0 to 100	x	x	x			
POPSC	Oxidizer Pump Primary Seal Cavity	PO6	0 to 50	x					
POTI-1P	Oxidizer Turbine Inlet	TG3	0 to 200	x					
POTO-1P	Oxidizer Turbine Outlet	TG4	0 to 100	x					
POUT	Oxidizer Ullage Tank		0 to 100	x					
PPTD	Photocon Cooling Water (Downstream)		0 to 100	x					
PPTU	Photocon Cooling Water (Upstream)		0 to 100	x					
PPUVI	Propellant Utilization Valve Inlet	PO8	0 to 2000	x					
PPUVO	Propellant Utilization Valve Outlet	PO9	0 to 1000	x					
PTCFJP	Thrust Chamber Fuel Jacket Purge		0 to 200	x					
PTEM	Turbine Exhaust Manifold	TG5	0 to 50	x					
PTM	Tapoff Manifold	GG2b	0 to 1500	x					
PTM-L	Tapoff Manifold	GG2b	0 to 500	x		x			
	Speeds		rpm						
NFP-1	Fuel Pump	PFV	0 to 33000		x				
NFP-2	Fuel Pump	PFV	0 to 33000	x		x(3)			
NFP-3	Fuel Pump	PFV	0 to 33000			x			

TABLE III-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Speeds		rpm						
NOP-1	Oxidizer Pump	POV	0 to 12000		x				
NOP 2	Oxidizer Pump	POV	0 to 12000	x		x(3)			
NOP-3	Oxidizer Pump	POV	0 to 12000			x			
	Temperatures		°F						
TA-1	Test Cell North		-50 to 800	x					
TA-2	Test Cell East		-50 to 800	x					
TA-3	Test Cell South		-50 to 800	x					
TA-4	Test Cell West		-50 to 800	x					
TECP-1P	Electrical Control Assembly	NST1a	-300 to 200	x					
TFAS1J	Augmented Spark Igniter Fuel Injection	IFT2	-425 to 100	x		x			
TFBM	Fuel Bypass Manifold	GG2b	-425 to 100	x					
TFCO	Film Coolant Orifice	IFT1	-425 to -375	x					
TFD-Avg.	Fire Detection Average		0 to 1000	x			x		
TFDFTA	Fire Detect Fuel Turbine Manifold Area		0 to 500	x					
TFDMFVA	Fire Detect Main Fuel Valve Area		0 to 500	x					
TFDMOVA	Fire Detect Main Oxidizer Valve Area		0 to 500	x					
TFDODA	Fire Detect Oxidizer Dome Area		0 to 500	x					
TFDTDA	Fire Detect Tapoff Duct Area		0 to 500	x					
TFJ-1P	Fuel Injection	CFT2	-425 to -300	x			x		
TFJ-2P	Fuel Injection	CFT2a	-425 to 100	x		x	x		
TFPBS	Fuel Pump Balance Piston Sump	PFT4	-425 to -375	x			x		
TFPD-1P	Fuel Pump Discharge	PFT1	-425 to -300	x	x				
TFPD-2P	Fuel Pump Discharge	PFT1	-425 to 100	x					
TFPI-1	Fuel Pump Inlet	KFT2	-425 to -400	x					x
TFPI-2	Fuel Pump Inlet	KFT2a	-425 to 100	x					x
TFPRS-1	Fuel Pump Rear Support		-400 to 1800	x					
TFPRS-2	Fuel Pump Rear Support		-400 to 1800	x					
TFPRS-3	Fuel Pump Rear Support		-400 to 1800	x					
TFRT-1	Fuel Run Tank		-425 to -400	x					
TFRT-3	Fuel Run Tank		-425 to -400	x					

TABLE I-1 (Continued)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Temperatures		°R						
TFTI-1P	Fuel Turbine Inlet	GGT3	0 to 1800	x					
TFTI-3	Fuel Turbine Inlet	TGT1	300 to 2400	x			x		
TFTI-4(4)	Fuel Turbine Inlet	GGT2	300 to 2000	x			x		
TFTO(4)	Fuel Turbine Outlet	GG?	100 to 1200	x					
TFVC	Fuel Repress at Customer Connect Panel		-300 to -100	x					
TFVL	Fuel Repress Nozzle Inlet	KHPT1	-300 to -100	x					
THFSL(2)	Helium Tank Supply Line		0 to 150	x					
THFT-1P	Helium Tank	NNT1	-200 to 150	x					x
THETS-1	Helium Tank Surface		0 to 500	x					
THETS-2	Helium Tank Surface		0 to 500	x					
TMFVS-1	Main Fuel Valve Skin (Outer Wall)		-425 to 100	x					
TMFVS-2	Main Fuel Valve Skin (Inner Wall)		-425 to 100	x					
TNODP	**Oxidizer Dome** Purge at Customer Connect		-250 to 200	x					
TOIML	Oxidizer Idle-Mode Line	POT5	-300 to 100	x					
TOIJ	Oxidizer Injec.	COT1	-300 to 1200	x		x			
TOPBC	Oxidizer Pump Bearing Cool-ant	POT4	-300 to -250	x		x			
TOPD-1P	Oxidizer Pump Discharge	POT3	-300 to -250	x					
TOPD-2P	Oxidizer Pump Discharge	POT3	-300 to 100	x					
TOPI-1	Oxidizer Pump Inlet	KOT2	-310 to -250	x					x
TOPI-2	Oxidizer Pump Inlet	KOT2a	-310 to 100	x					x
TORT-1	Oxidizer Run Tank		-300 to -285	x					
TORT-3	Oxidizer Run Tank		-300 to -285	x					
TOTI-1P	Oxidizer Tur-bine Inlet	TGT3A	0 to 1200	x					
TOTM-1	Oxidizer Tur-bine Manifold		-300 to 1000	x					
TOTM-2	Oxidizer Tur-bine Manifold		-300 to 1000	x					
TOTO-1P	Oxidizer Tur-bine Outlet	TGT4	0 to 1000	x					

TABLE III-1 (Concluded)

AEDC Code	Parameter	Tap No.	Range	Digital Data System	Magnetic Tape	Oscillograph	Strip Chart	Event Recorder	X-Y Plotter
	Temperatures		°F						
TPIP-1P	Instrumentation Package		-300 to 200	x					
TPTU	Photocon Cooling Water (Upstream)		0 to 300	x					
TTCIS-1[3]	Thrust Chamber Internal Skin		-300 to 1500	x			x[2]		
TTCIS-2[3]	Thrust Chamber Internal Skin		-300 to 1500	x					
TTCIS-3[3]	Thrust Chamber Internal Skin		-300 to 1500	x					
TTCP	Thrust Chamber Purge		-250 to 200	x					
TTCT-E1	Thrust Chamber Tube (Exit)		-425 to 500	x					
TTCT-E2	Thrust Chamber Tube (Exit)		-425 to 500	x					
TTCT-T1	Thrust Chamber Tube (Throat)		-425 to 500	x			x		
TTCT-T2	Thrust Chamber Tube (Throat)		-425 to 500	x					
TTM	Tapoff Manifold		0 to 2000	x		x	x[3]		
	Vibrations		g's						
UFPR	Fuel Pump Radial	PZA-1	450 Peak		x				
UFTR	Fuel Turbine Radial	TZA	450 Peak		x				
UOPR	Oxidizer Pump Radial	PZA-2	300 Peak		x				
UTCD-1	Thrust Chamber Dome	FZA-1a	100 Peak		x	x			
UTCD-2	Thrust Chamber Dome	FZA-2	100 Peak		x	x			
UTCD-3	Thrust Chamber Dome	FZA-3	100 Peak		x	x			
UTCT-1	Thrust Chamber Throat		300 Peak		x				
UTCT-2	Thrust Chamber Throat		300 Peak		x				
	Voltage		volts						
VCB	Control Bus		0 to 36	x					
VIB	Ignition Bus		0 to 36	x					
VIDA-1	Ignition Detect Amplifier		9 to 16	x					
VIDA-2	Ignition Detect Amplifier		9 to 16	x					
VPUVEP	Propellant Utilization Valve Telemetry Potentiometer Excitation		0 to 5	x					

1 Employed on Tests J4-1902-11 and -12
2 Employed on Test J4-1902-08 Only
3 Employed on Tests J4-1902-08 and -11 Only
4 Employed on Test J4-1902-12 Only
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13. ABSTRACT

Six firings of the Rocketdyne J-2S rocket engine were conducted in Test Cell J-4 of the Rocket Test Facility on April 2, May 6, and May 9, 1969. These firings were accomplished during test periods J4-1902-08, -11, and -12 at pressure altitudes at engine start ranging from 80,500 to 101,500 ft. Objectives were to develop high-thrust idle-mode operation capability and to develop transition capability from high-thrust idle mode to main stage without utilization of the solid-propellant turbine starter. The first attempt at high-thrust idle-mode operation (firing 08A) was not successful; however, during test periods 11 and 12 transition was accomplished from low to high thrust (approximately 4000- to 50,000-lbf thrust) idle mode and from high-thrust idle mode to main stage during firing 12C.

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